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REPORT FOR CONSULTATION ON THE MERRIMACK VALLEY-SOUTHERN NEW HAMPSHIRE INTERSTATE AIR QUALITY CONTROL REGION (MASSACHUSETTS AND NEW HAMPSHIRE)

National Air Pollution Control Administration
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REPORT FOR CONSULTATION ON THE MERRIMACK VALLEY-SOUTHERN NEW HAMPSHIRE INTERSTATE AIR QUALITY CONTROL REGION (MASSACHUSETTS AND NEW HAMPSHIRE)

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

NATIONAL TECHNICAL INFORMATION SERVICE

The Clean Air Act requires the designation of 'air quality control regions' prior to the adoptation of air quality standards and plans for implementation of the standards. A study was thus conducted of _____

The results ~~of the~~ of the study are presented in the report. It consists of a description of the region, an emission inventory, meteorology, and urban factors.

REPORT FOR CONSULTATION ON THE

MERRIMACK VALLEY-SOUTHERN NEW HAMPSHIRE

INTERSTATE AIR QUALITY CONTROL REGION

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
National Air Pollution Control Administration

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PREFACE

The Clean Air Act, as amended, directs the Secretary of Health, Education, and Welfare to designate "air quality control regions" to provide a basis for the adoption of regional air quality standards and the implementation of those standards. The Act stipulates that the designation of a region shall be preceded by consultation with appropriate State and local authorities. This report is intended to provide the basic background information needed for the consultation. It proposes boundaries for the Merrimack Valley-Southern New Hampshire Interstate Air Quality Control Region and discusses the factors which are the basis of the proposed boundaries.

The Region* boundaries proposed in this report remain subject to revisions suggested during consultation with State and local authorities. Formal designation of the Region will be made only after a careful review of all opinions and suggestions submitted during the consultation process.

The National Air Pollution Control Administration appreciates assistance received from the States of Massachusetts and New Hampshire, and the local governments and planning agencies in the area.

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*For the purposes of this report, the word "region," when capitalized, will refer to the Merrimack Valley-Southern New Hampshire Interstate Air Quality Control Region.

INTRODUCTION

THE REGIONAL APPROACH

Air pollution in the urban areas of the United States is a regional problem which frequently extends across governmental boundaries. Since air pollution problems are rarely confined to any single municipality or county, and are often not confined within a single State, successful control requires coordinated planning, standard setting, and enforcement by the several political jurisdictions which share a common problem. To date, State and local governments across the Nation have only begun to develop a regional approach to air pollution control.

The Clean Air Act, as amended, provides a regional approach which depends upon coordination and cooperation among all levels of government--municipal, county, State, and Federal. To set in motion the machinery for regional air pollution control, the Department of Health, Education, and Welfare designates air quality control regions (following consultation with State and local officials), issues air quality criteria, and publishes reports on control techniques. The designation of region boundaries indicates which State and local jurisdictions will be involved in a regional air pollution control effort. The air quality criteria indicate the extent to which various concentrations of air pollutants are harmful to health and damaging to property. The reports on control techniques provide information

on the costs and effectiveness of various techniques for controlling air pollutant emissions.

After the Department of Health, Education, and Welfare completes these initial steps, State governments develop air quality standards and plans for implementation of such standards within the boundaries of designated air quality control regions. An air quality standard for a region defines the desired limit of concentration of a pollutant in its ambient air. It represents the level of air quality which the regional control program will attempt to achieve. An implementation plan is a blueprint of the steps which will be taken to attain chosen regional air quality standards within a reasonable time. The Clean Air Act requires that within 90 days after the Secretary of Health, Education, and Welfare has designated the region, State Governors must submit letters indicating that they intend to set air quality standards for those pollutants for which criteria and control technology documents have been issued. They have an additional 180 days to set the standards. The procedure for setting standards includes a public hearing which allows residents of a region to express their views concerning the proposed standards. The Governors are required to submit to the Secretary, within an additional 180 days, plans for the implementation of the standards which have been adopted.

The Department of Health, Education, and Welfare reviews air quality standards and implementation plans in order to ascertain their consistency with the provisions of the Act.

When air quality standards and implementation plans are approved, States proceed to prevent and control air pollution in accordance with those standards and plans. This system for establishing a regional approach to air pollution control is outlined in Figure 1.

DESIGNATION OF AIR QUALITY CONTROL REGIONS

Designation of an air quality control region is one of the first steps in the regional approach to air pollution control. Section 107 (a) (2) of the Clean Air Act, as amended, directs the Secretary, Department of Health, Education, and Welfare to make such designations. The portions of the section relevant to this discussion state:

> "...The Secretary, after consultation with appropriate State and local authorities shall...designate air quality control regions based on jurisdictional boundaries, urban-industrial concentrations, and other factors including atmospheric areas necessary to provide adequate implementation of air quality standards. The Secretary may...revise the designation of such regions...The Secretary shall immediately notify the Governor or Governors of the affected State or States of such designation."

Procedure for Designation of Regions

Figure 2 illustrates the procedures used by the National Air Pollution Control Administration (NAPCA) for designating air quality

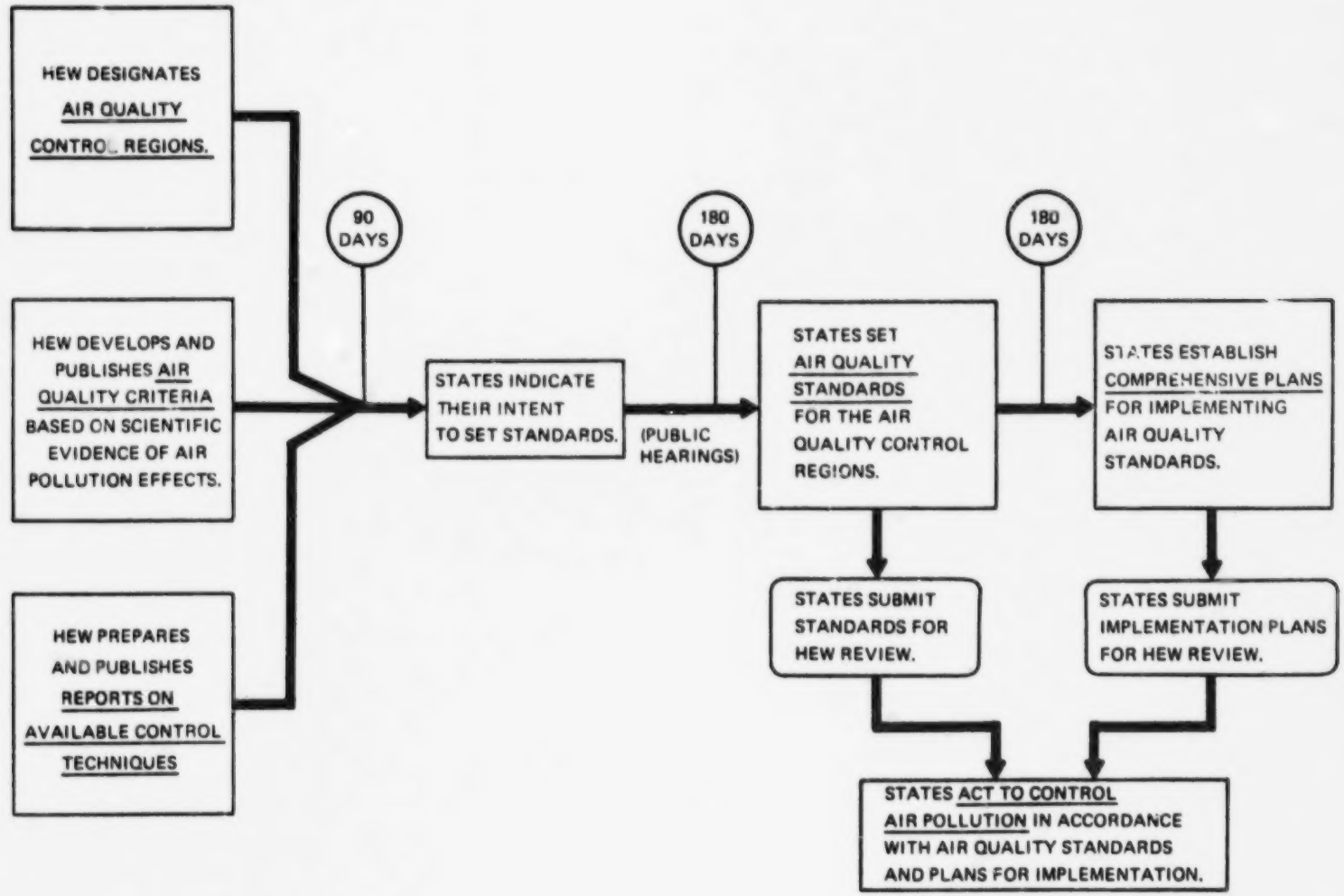
HEW DESIGNATES AIR QUALITY CONTROL REGIONS.
HEW DEVELOPS AND PUBLISHES AIR QUALITY CRITERIA BASED ON SCIENTIFIC EVIDENCE OF AIR POLLUTION EFFECTS.
HEW PREPARES AND PUBLISHES REPORTS ON AVAILABLE CONTROL TECHNIQUES
90 DAYS
STATES INDICATE THEIR INTENT TO SET STANDARDS.
180 DAYS
(PUBLIC HEARINGS)
STATES SET AIR QUALITY STANDARDS FOR THE AIR QUALITY CONTROL REGIONS.
180 DAYS
STATES ESTABLISH COMPREHENSIVE PLANS FOR IMPLEMENTING AIR QUALITY STANDARDS.
STATES SUBMIT STANDARDS FOR HEW REVIEW.
STATES SUBMIT IMPLEMENTATION PLANS FOR HEW REVIEW.
STATES ACT TO CONTROL AIR POLLUTION IN ACCORDANCE WITH AIR QUALITY STANDARDS AND PLANS FOR IMPLEMENTATION.

FIGURE 1 - Flow Diagram for Action to Control Air Pollution on a Regional Basis, Under the Clean Air Act

ENGINEERING EVALUATION
• EMISSIONS INVENTORY
• TOPOGRAPHY
• METEOROLOGY
• AIR QUALITY ANALYSIS
EXISTING AIR QUALITY DATA
DIFFUSION MODEL OUTPUT
URBAN FACTORS EVALUATION
• JURISDICTIONAL BOUNDARIES
• URBAN INDUSTRIAL CONCENTRATIONS
• COOPERATIVE REGIONAL ARRANGEMENTS
• PATTERNS AND RATES OF GROWTH
• EXISTING STATE AND LOCAL AIR POLLUTION CONTROL PROGRAMS & LEGISLATION
PRELIMINARY DELINEATION OF REGIONS
CONSULTATION WITH STATE AND LOCAL OFFICIALS
FORMAL DESIGNATION BY SECRETARY HEW

FIGURE 2 - Flow Diagram for the Designation of Air Quality Control Regions

control regions.

After evaluating relevant technical and urban factors in a region, the National Air Pollution Control Administration publishes a proposed delineation of its boundaries. At the same time, NAPCA sets a time and place for a consultation meeting and distributes to State and local authorities a report of the evaluation study (such as this "Report for Consultation") which includes the boundary proposal. At the consultation meeting State and local authorities are encouraged to present fully their views and suggestions concerning the proposed boundaries of the region. Interested parties who do not have official status may submit comments in written form for the record. After careful review of all suggestions and opinions submitted for the record by interested parties, the Secretary of Health, Education, and Welfare makes a formal designation of the region boundaries and notifies the Governor(s) of the State(s) affected by the designation.

The Size of a Region

As stipulated in Section 107 (a) (2), the designation of air quality control regions should be based on "jurisdictional boundaries, urban-industrial concentrations and other factors including atmospheric areas necessary to provide adequate implementation of air quality standards." This language suggests a number of objectives which are important in determining how

large an air quality control region should be. Basically, these objectives can be divided into three separate categories.

First, a region should be self-contained with respect to air pollution sources and receptors. Unfortunately, since air pollutants can travel long distances, it is impractical if not impossible to delineate regions which are completely self-contained. The air over a region will usually have at least trace amounts of pollutants from external sources. During episodic conditions, such contributions from external sources may even reach significant levels. Conversely, air pollution generated within a region and transported out of it can affect external receptors to some degree. It would be impractical and inefficient to make all air quality control regions large enough to encompass these low-level trace effects. The geographic extent of trace effects overestimates the true problem area which should be the focus of air pollution control efforts. Thus, the first objective, that a region be self-contained, becomes a question of relative magnitude and frequency. The dividing line between "important influence" and "trace effect" will be a matter of judgment. The judgment should be based on estimates of the impact a source has upon a region, and the level of pollution to which receptors are subjected. In this respect, annual and seasonal data on pollutant emissions and ambient air concentrations are a better measure of relative

influence than short term data on episodic conditions. In summary, a region should include most of the important sources in the area as well as most of the people and property affected by those sources.

The second general objective requires that regional boundaries be designed to meet not only present conditions but also future conditions. In other words, the region should include areas where industrial and residential expansion are likely to create air pollution problems in the foreseeable future. This objective requires careful consideration of existing metropolitan development plans, expected population growth, and projected industrial expansion. Such considerations should result in the designation of regions which will contain the sources and receptors of regional air pollution for a number of years to come. Of course, regional boundaries need not be permanently fixed, once designated. Boundaries should be reviewed periodically and altered when changing conditions warrant readjustment.

The third objective is that regional boundaries should be compatible with and even foster unified and cooperative governmental administration of the air resource throughout the region. Because air pollution usually extends across governmental boundaries, the cooperation of several governmental bodies is required for the solution of a common set of air pollution problems. In this regard, the established patterns of governmental coopera-

tion on a range of urban problems is an important consideration, and the pattern of cooperation among existing air pollution control programs is a particularly relevant factor. In general, administrative considerations would argue against the division of governmental jurisdictions. Although it would be impractical to preserve State jurisdictions undivided, usually it is possible to preserve the unity of county governments by including or excluding them in their entirety. Occasionally, even this would be impractical due to a county's large size, wide variation in level of development, or striking topographical features.

To the extent that any two of the above three objectives lead to incompatible conclusions concerning region boundaries, the region must represent a reasonable compromise. A region should represent the best way of satisfying the three objectives simultaneously.

As noted above, the evaluations of relevant technical, urban, and governmental factors form the basis of the boundary proposals published by NAPCA. The technical factors study takes account of the location of pollution sources and the geographic extent of serious pollutant concentrations in the ambient air. Pollution sources are identified through an inventory of emissions from power generation, industrial operations, space heating, waste disposal, and other pollution-causing activities. The transport and distribution of pollutants in the ambient air are

analyzed on the basis of measured air quality data, the location of emissions, meteorological data, and topographic information. A mathematical diffusion model which predicts ambient pollution concentrations from information on emissions and meteorology can be used in areas where irregular topographical features would not invalidate the theoretical model. As a whole, the technical factors study indicates how large the air quality control region should be in order to encompass most pollution sources and most people and property affected by those sources.

The study of urban factors takes account of a different set of considerations. It discusses the location of urban and industrial concentrations and expected patterns of urban growth. As a whole, the urban factors study indicates how large a region should be in order to encompass expected regional growth.

The evaluation of the regional governmental organizations discusses the planning agencies, councils of government, and state and local air pollution control programs. This study attempts to define the combination of counties which, through cooperative regional arrangements, would best work together towards achieving clean air in the region.

The body of this report contains a proposal for the boundaries of the Merrimack Valley-Southern New Hampshire Interstate Air Quality Control Region, following evaluation of technical, urban, and governmental factors. The report is intended to

serve as the background document for the formal Consultation between the National Air Pollution Control Administration and the appropriate State and local authorities.

EVALUATION OF URBAN FACTORS

Urbanization and industrialization are important considerations in determining air quality control region boundaries. This discussion of the Merrimack Valley-Southern New Hampshire area will begin by describing the major geographic characteristics of the area which have affected the location and extent of development in the past. Then the present distribution of population and economic activity will be described. Finally, factors likely to affect future urbanization in the area will be summarized.

GEOGRAPHY AND PAST DEVELOPMENT OF REGION

The Merrimack Valley-Southern New Hampshire area selected for study lies between the Metropolitan Boston Air Quality Control Region in Massachusetts and the proposed Metropolitan Portland Air Quality Control Region in Maine (Figure 3). The study area includes the New Hampshire Counties of Hillsborough, Merrimack, Rockingham, and Strafford, and portions of Middlesex and Essex Counties in Massachusetts (Figure 4). One hundred and eight cities and towns in New Hampshire and twenty-eight cities and towns in Massachusetts are located in the study area (Figures 5 and 6). The major urban concentrations are the Standard Metropolitan Statistical Areas (SMSA's) of Manchester, Lowell, and Lawrence-Haverhill, and the

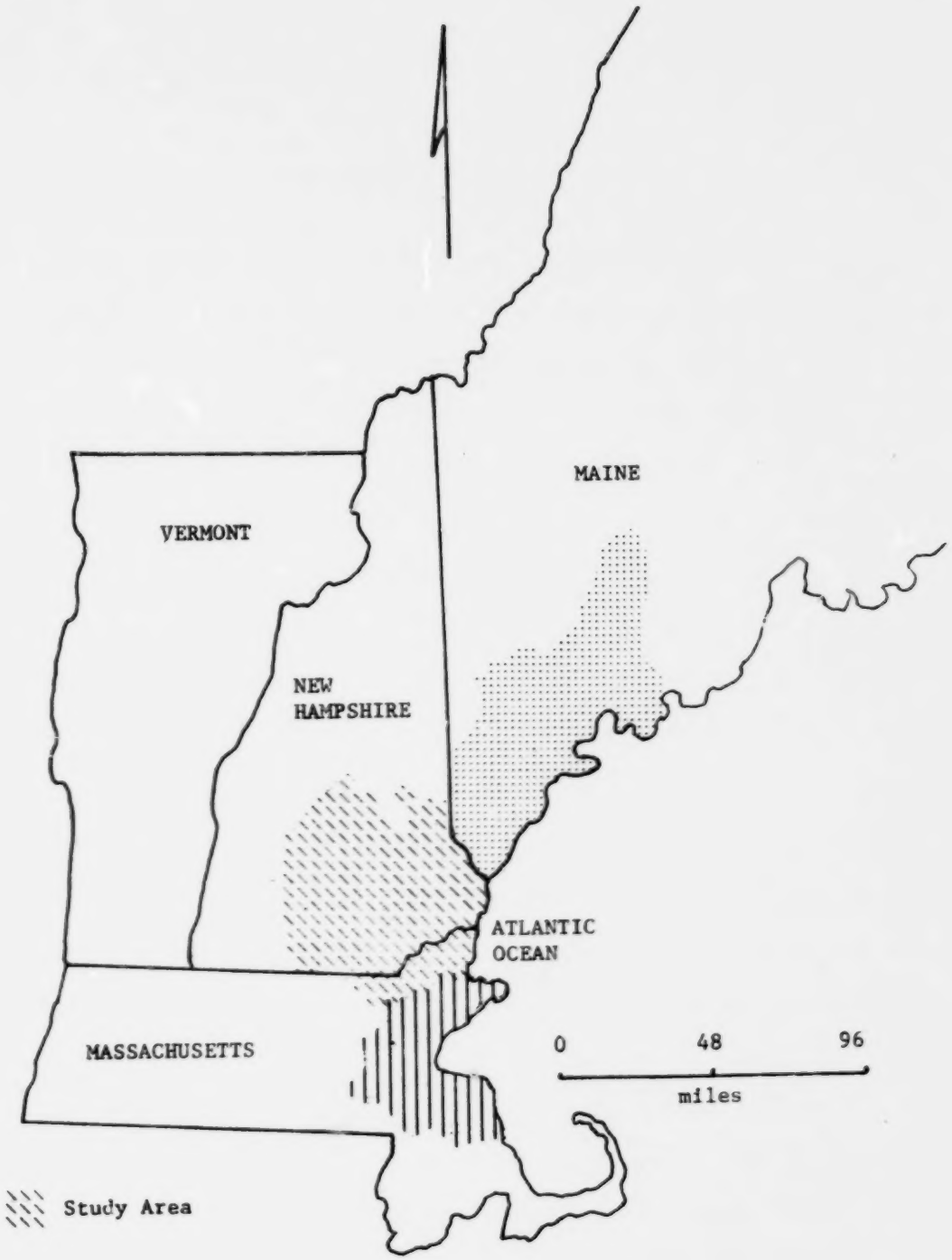

FIGURE 3 - Relationship of Merrimack Valley-Southern New Hampshire Study Area to Metropolitan Boston Air Quality Control Region and Proposed Metropolitan Portland, Maine, Air Quality Control Region

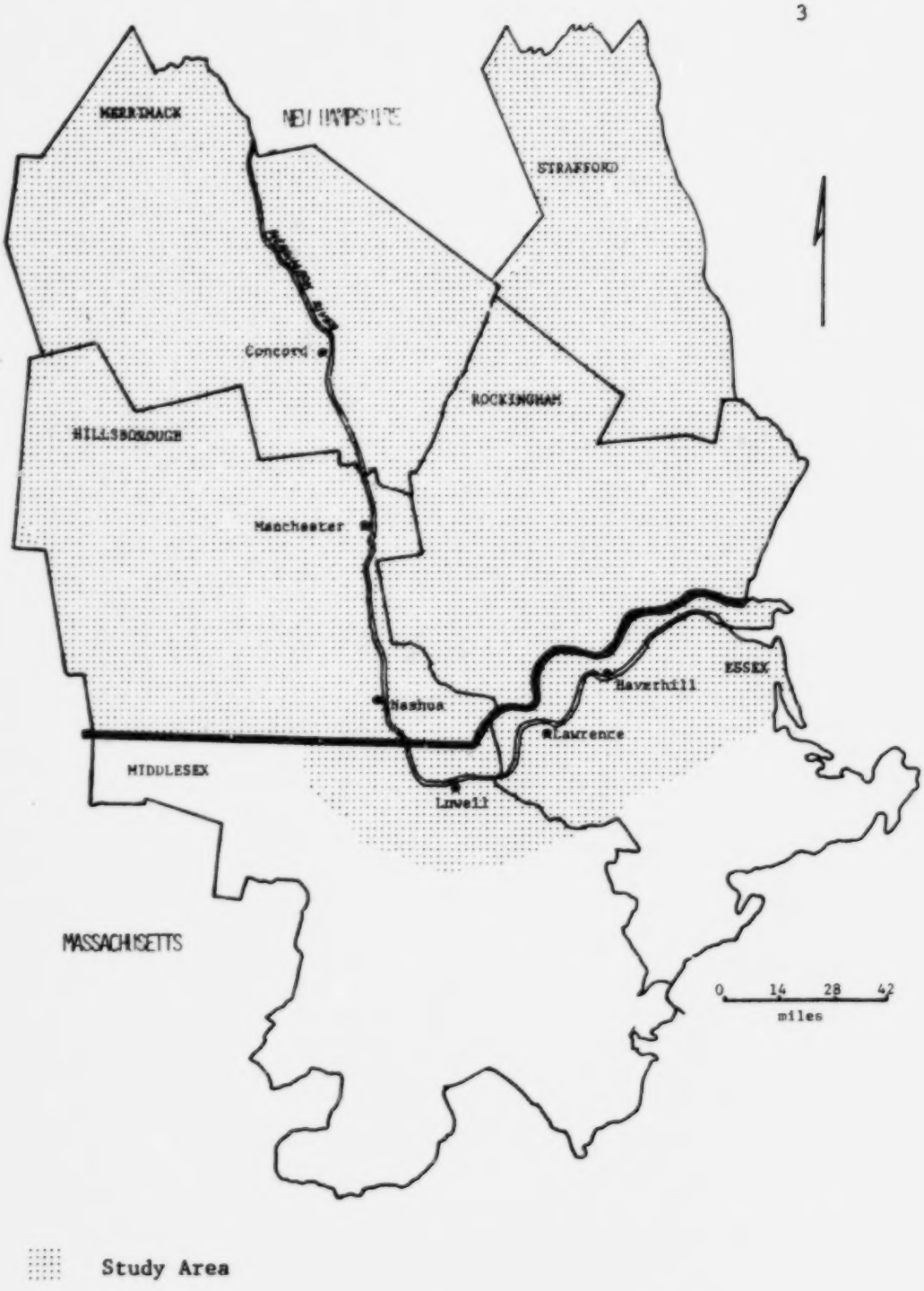

FIGURE 4 - Relationship of Merrimack Valley-Southern New Hampshire Study Area to New Hampshire and Massachusetts Counties

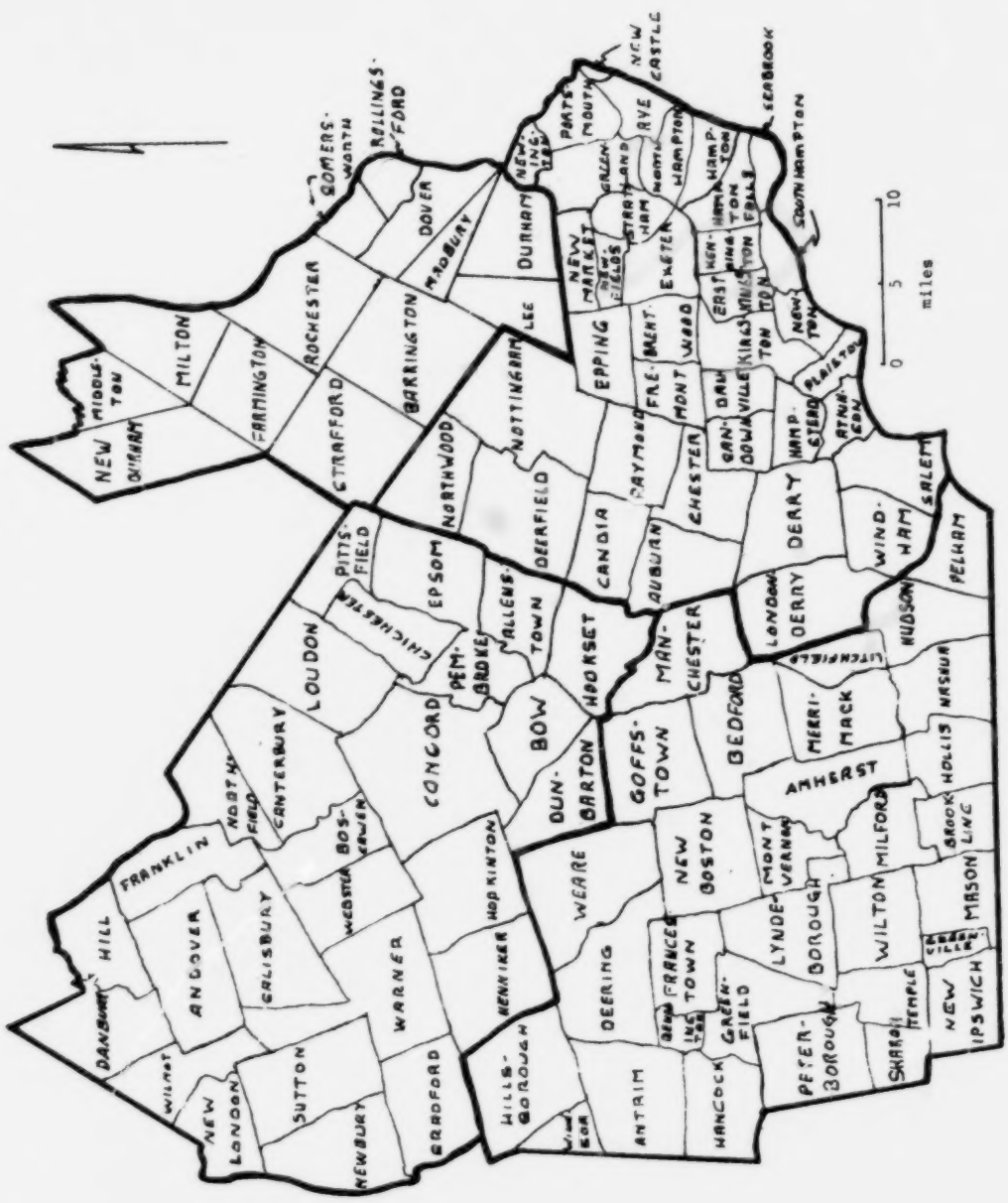

FIGURE 5 - Cities and Towns in New Hampshire Portion of Merrimack Valley-Southern New Hampshire Study Area

FIGURE 6 - Cities and Towns in Massachusetts Portion of Merrimack Valley-Southern New Hampshire Study Area

cities of Dover, Portsmouth, Concord, Derry, Nashua-Hudson, and Newburyport (Figure 7). The cities included in the SMSA's are listed in Table I.

The study area lies in the foothills of New Hampshire's White Mountains and its terrain varies from rocky hills, forests, and sparse clearings, to fertile river valleys, lakes, ponds, and occasional swamps. Land elevations range from a maximum of about 2,000 feet in northern Merrimack County down to sea level on the Atlantic Coast. The Merrimack River flows south through the heart of the New Hampshire portion of the study area and into Massachusetts where it turns northeastward toward the Atlantic Ocean. At the eastern edge of the study area, on the boundary between the States of New Hampshire and Maine, the Salmon Falls and Piscataqua Rivers also flow south into the Atlantic.

The location of early settlement and later development was profoundly influenced by the geography of the area. While the first villages were established at the mouth of the Piscataqua River in 1623, settlement in the century to follow was mainly along the Merrimack River into the interior of Massachusetts and thence northward into New Hampshire. As frontier forts were established along the Merrimack, settlers developed farms on tillable valley lands along the water route. Fishing, hunting, and lumbering were developed also. By 1655, Billerica and Chelmsford had been created as Towns by the General Court of

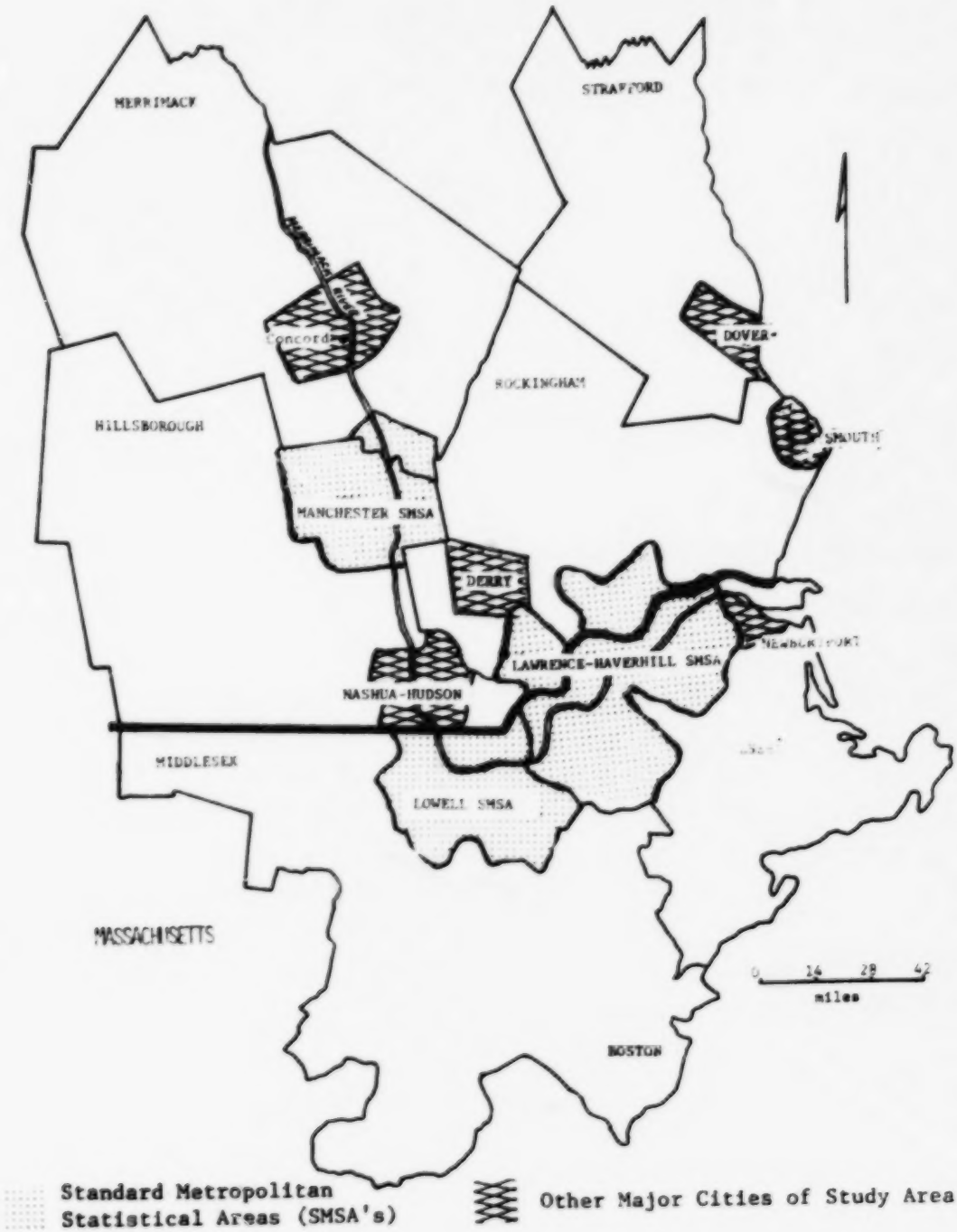

FIGURE 7 - Major Urban Concentrations in Merrimack Valley-Southern New Hampshire Study Area

Table 1

Cities and Towns Included in Standard Metropolitan Statistical Areas of Lawrence-Haverhill, Lowell, and Manchester

LAWRENCE-HAVERHILL SMSA

Massachusetts
- Lawrence
- Haverhill
- Andover
- Georgetown
- Groveland
- Merrimac
- Methuen
- North Andover
- West Newbury

New Hampshire
- Newton
- Plaistow
- Salem

LOWELL, MASSACHUSETTS, SMSA

- Lowell
- Billerica
- Chelmsford
- Dracut
- Tewksbury
- Tyngsborough
- Westford

MANCHESTER, NEW HAMPSHIRE, SMSA

- Manchester
- Bedford
- Goffstown
- Hooksett

Source: Office of Statistical Standards, Executive Office of the President, Bureau of the Budget, Standard Metropolitan Statistical Areas 1967.

Massachusetts. Some towns, now on opposite sides of the interstate boundary, were joined by legal ties in the earliest period. For example, Atkinson and Hampstead, New Hampshire, were founded as parts of Haverhill, Massachusetts; and South Hampton, New Hampshire, was originally part of Amesbury and Salisbury, Massachusetts.

During the late 1700's canals and locks were installed on the Merrimack to bypass the River's waterfalls and rapids. The canals and locks not only permitted upstream navigation large boats but also provided power for a later shift of manufacturing from small handicraft shopes to large-volume, mechanized industrial production. By 1815, canal construction had progressed to the point that heavy freight could move north on the River to Concord, thus establishing a major economic link among the settlements along the entire navigable course of the Merrimack.

Roads and turnpikes further reinforced these connections. They also drew Dover and Portsmouth into a closer relationship with the Merrimack Valley area. A farm-to-market road going from Dover to Haverhill in Western New Hampshire was begun in 1763 to take Connecticut River farm products to the seacoast region. From 1796 onward, numerous turnpike companies were chartered to build roads in the study area, the first turnpike going from Portsmouth to Concord via Durham.

An even greater consolidation of the Merrimack Valley-Southern New Hampshire region as a unified economic area occurred

with the construction of a vast railroad network, beginning in the 1830's. One important route connected Lowell to Concord via Nashua; another connected Haverhill, Massachusetts, to Dover via Exeter.

By the mid-1800's, ranks of red brick factory buildings, five to eight stories high, had risen on the banks of the Merrimack in many locations, notably in Manchester, Nashua, Lowell, Haverhill, and Lawrence. The buildings housed looms and other heavy machinery for mass production of textiles, shoes, and apparel. Thereafter, until the 1920's when the textile industry began its movement into the Southeastern States, a surge of industrialization in the Merrimack Valley reduced the agricultural population of the study area and boosted the population of its cities. During the first half of the 1800's, the population of the rural portions of the study area was further depleted by the migration of farmers to new lands in the Western United States. The cities, however, continued to add to their population gains from successive waves of immigration into the United States from Europe and Canada. Lowell, Lawrence, and Manchester, for example, had their greatest growth in this period (Figure 8).

Despite the diversion of much of the textile and leather industries out of the study area in the 1920's, no marked change

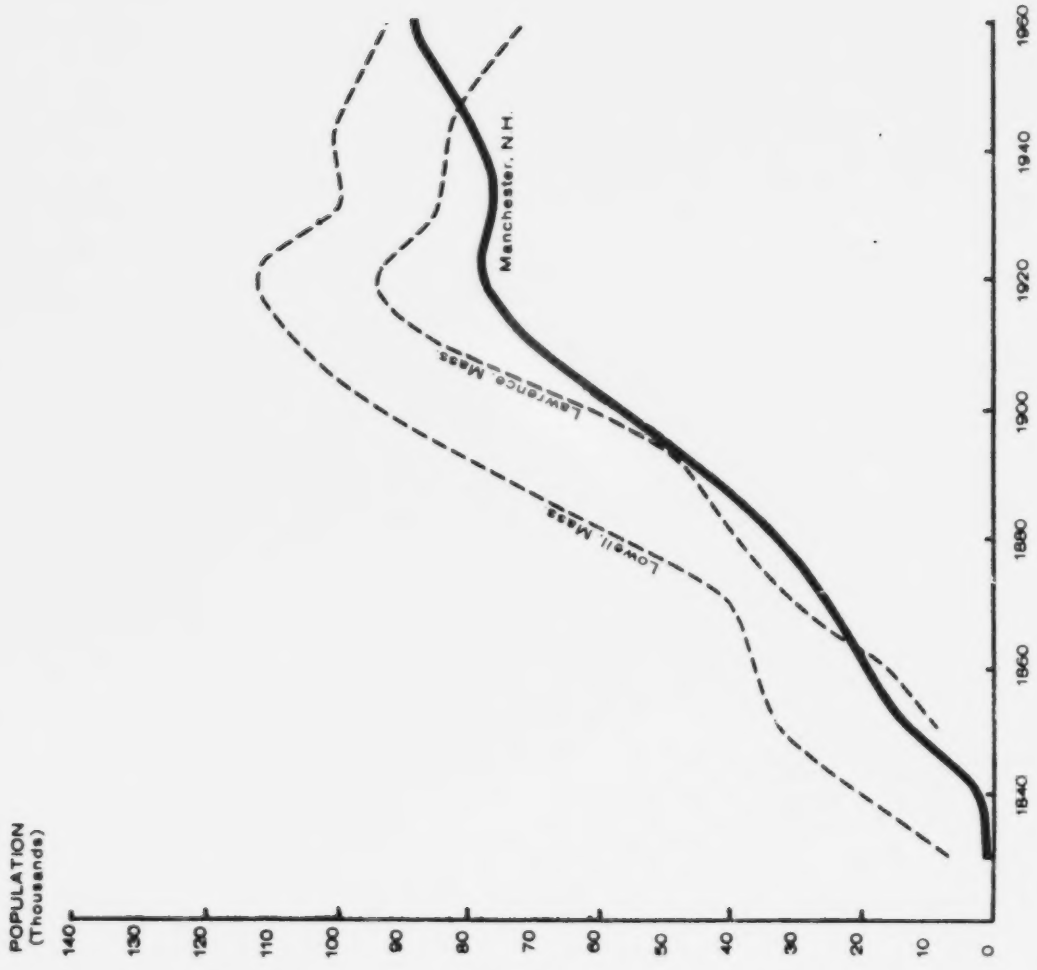

FIGURE 8 - Population Growth of Lowell and Lawrence, Massachusetts, and Manchester, New Hampshire, 1840-1960.

Source: Adapted from original Chart in Anderson-Nichols & Co., Inc. report for New Hampshire Department of Resources and Economic Development, Public Water Supply Study, Phase One Report, May, 1969.

in its industrial structure took place until after World War II. At that time, national defense technology needs and the Boston area's unique concentration of university intellectual capital led to research and development activities and to the stimulation of electronics and instrument manufacturing in northeastern Massachusetts and southeastern New Hampshire. Major branches of ordnance manufacturing were established in the study area as well as a Naval shipyard for the construction of nuclear submarines and a large Strategic Air Force base.

PRESENT POPULATION AND ECONOMIC ACTIVITY PATTERN OF REGION

Table II summarizes the most recently available population data for the Merrimack Valley-Southern New Hampshire study area. According to these data for 1965-66, the study area population totals 896,800, of whom 502,200 reside in the Lawrence-Haverhill, Lowell, and Manchester Standard Metropolitan Statistical Areas (SMSA's). Another 153,700 are found in six other major cities and towns--Newburyport in Massachusetts; and Concord, Derry, Dover, Hudson, Nashua, and Portsmouth in New Hampshire. Figure 7 (on p. 7 of preceding section) shows that these SMSA's, cities, and towns are located in a U-shaped curve of urban concentration south and east in the Merrimack Valley, and along the Piscataqua and Salmon River Valleys.

When population densities per square mile of city or township land area are plotted on a map, the outline of a U-shaped urban region is quite apparent (Figure 9). From Franklin in northern Merrimack County at one end of the "U" to Rochester in eastern Strafford County at the other, there is a virtually unbroken succession of cities and towns with population densities of 100 persons or more per square mile. In the sections of the "U" around Nashua and Hudson, its base from Pepperell to Seabrook, and the area north along the Atlantic Coast and the Piscataqua River, densities of 200 persons or more per square mile predominate. Salem, Dracut, Billerica, Tewksbury, Andover, Groveland,

Table II

Estimated Population, Merrimack Valley-Southern New Hampshire Interstate Study Area, 1965-66 a/
(thousands of persons)

Total			896.8
Standard Metropolitan Statistical Areas			502.2
Lawrence-Haverhill SMSA (Mass.-N.H.)		214.7	
Massachusetts portion	193.2		
New Hampshire portion	21.5		
Lowell SMSA (Mass.)		180.0	
Manchester SMSA (N.H.)		107.5	
Other major cities and towns			153.7
Newburyport (Mass.)		14.7	
Concord (N.H.)		29.1	
Derry (N.H.)		10.2	
Dover (N.H.)		22.2	
Hudson (N.H.)		9.3	
Nashua (N.H.)		45.3	
Portsmouth (N.H.)		22.9	
All other areas			240.9

Sources: The Commonwealth of Massachusetts, Division of Employment Security, Massachusetts Cities and Towns, 1958-1966; New Hampshire Department of Resources and Economic Development, Population Projections, New Hampshire, Concord, New Hampshire, May 1969.

a/ Massachusetts data are for 1965 and derived from the Massachusetts State Census of Population for that year; New Hampshire data are estimates for 1966 of New Hampshire Department of Resources and Economic Development, Office of Planning and Research.

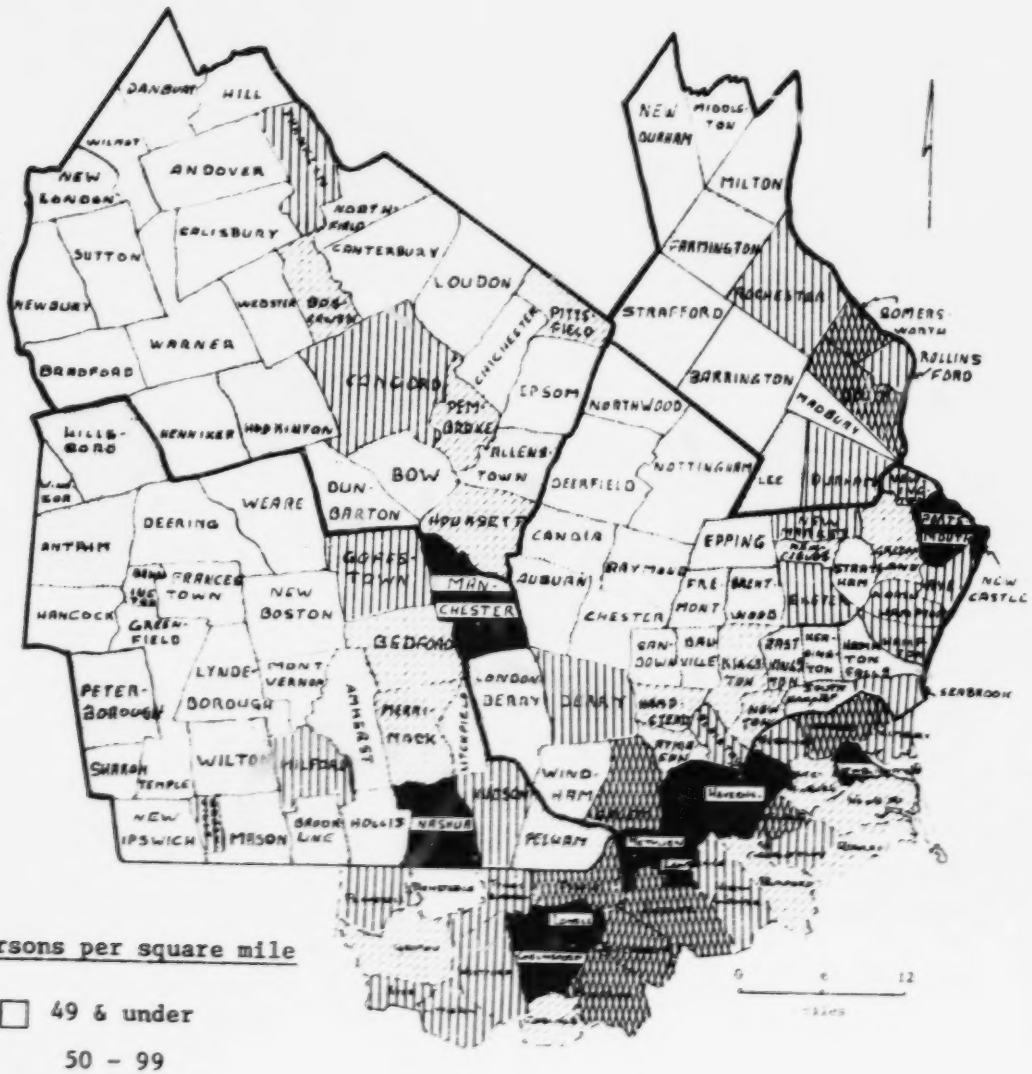

FIGURE 9 - Population Densities of Cities and Towns, Merrimack Valley-Southern New Hampshire Study Area, 1965-66

Amesbury, Dover, and Somersworth have densities of between 500 and 1,000 persons per square mile. Manchester, Nashua, Lowell, Chelmsford, Methuen, Lawrence, Haverhill, Newburyport, New Castle, and Protsmouth have densities exceeding 1,000 persons per square mile.

Employment data for 1966 shown in Table III confirm the overwhelmingly industrial character of the entire study area. As may be expected, nearly all of the civilian employment in the Lawrence-Haverhill, Lowell, and Manchester SMSA's is in non-agricultural occupations. Similar information on the remainder of the study area is not available, but the estimated proportion of nonagricultural employment in the non-metropolitan areas of the States of Massachusetts and New Hampshire as a whole--about 97 percent in both States--may be taken as a rough guide.

Manufacturing accounts for a large share of nonagricultural employment throughout the study area. As Table IV shows, the ratio of manufacturing to total nonagricultural employment in 1967 ranged from a low of 31 percent in Rockingham County to a high of 67.9 percent in Strafford County. The Manchester, Lowell, and Lawrence-Haverhill SMSA's had ratios of 37.5, 39.7, and 51.1 percent, respectively.

Table III

Estimated Shares of Agricultural and Nonagricultural Employment in Total Civilian Employment, 1966
(percentages of total)

	Total Civilian Employment	Employment in Agriculture, Forestry, and Fisheries	Non-Agricultural Employment
Metropolitan Areas (Lawrence-Haverhill, Lowell, and Manchester)	100.0	0.9	99.1
Nonmetropolitan Areas			
State of Massachusetts	100.0	2.7	97.3
State of New Hampshire	100.0	3.2	96.8

Source: Computed from estimates published in National Planning Association, Economic and Demographic Projections for States and Metropolitan Areas, Report No. 68-R-1, January, 1969.

Table IV

Total Nonagricultural Employment and Manufacturing Employment, Merrimack Valley-Southern New Hampshire Study Area, 1967

	Total Nonagricultural Employment (000)	Manufacturing Employment	
		Number (000)	Percent of Total
Massachusetts Portion			
Lawrence-Haverhill SMSA [a]	76.6	39.2	51.1
Lowell SMSA	48.7	19.5	39.7
New Hampshire Portion			
Hillsborough County	76.3	39.3	51.4
Merrimack County	20.2	8.8	43.3
Rockingham County [a]	21.1	6.6	31.0
Strafford County	19.6	13.3	67.9
Manchester SMSA	48.7	18.3	37.5

Sources: New Hampshire county data from U. S. Department of Commerce, Bureau of the Census, County Business Patterns, 1967.

Massachusetts and New Hampshire SMSA data from U. S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings Statistics for States and Areas, 1939-67, Bulletin No. 1370-5, August, 1968.

a/ Data for Salem, Plaistow, and Newton, New Hampshire, are included in both Lawrence-Haverhill SMSA and in Rockingham County, New Hampshire.

However, there is evidence of divergent trends in the growth of manufacturing employment within the study area. Table V shows that in the decade, 1959-69, the Lawrence-Haverhill, Lowell, and Manchester SMSA's as well as the Massachusetts cities and towns outside of the SMSA's reduced their manufacturing employment. On the other hand, the four New Hampshire counties of the study area all showed manufacturing employment gains. The increases in Hillsborough and Merrimack Counties are particularly significant because they occurred despite the reduction in manufacturing employment in the Manchester SMSA included in the figures for the two counties.

The reasons for the gains in the New Hampshire portion of the study area and the reductions in the Massachusetts portion are suggested in the analysis shown in Table VI. The New Hampshire counties gained because they were able to increase employment in the nondurable goods industries (mainly textiles and leather), to increase employment in the durable goods industries (mainly machinery and electrical manufactures), or both. In the case of Hillsborough County, a huge increase of 10,100 jobs in durables manufacturing enabled it to absorb a loss of 3,000 jobs in nondurables and yet to emerge with a sizable net growth in manufacturing employment. In the Massachusetts portion of the study area (in the period 1959-67), the Lawrence-Haverhill SMSA had increases in durable goods manufacturing employment but

Table V

Trends in Manufacturing Employment, Merrimack Valley-Southern New Hampshire Study Area, 1959-69
(thousands of employees)

	Average Manufacturing Employment 1959	1964	1969	Change 1959-69
Massachusetts Portion				
Lawrence-Haverhill SMSA	39.4	41.5	38.5	- .9
Lowell SMSA	21.8	20.0	20.3	- 1.5
Cities and towns not in either SMSA [a/]	7.7	5.6	6.1 [b/]	- 1.6 [c/]
New Hampshire Portion				
Hillsborough County	33.5	33.3	40.6 [d/]	+ 7.1
Merrimack County	7.2	8.4	9.0 [d/]	+ 1.9
Rockingham County	6.5	6.9	8.0 [d/]	+ 1.5
Strafford County	11.9	11.3	13.2 [d/]	+ 1.3
Manchester SMSA	18.7	16.7	17.0	- 1.7

Sources: All SMSA data are for total manufacturing employment and from U. S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings Statistics for States and Areas, 1939-67, Bulletin No. 1370-5, August, 1968; and Employment and Earnings, Vol. 16, No. 11, May, 1970. Other data are for insured manufacturing employment and from Commonwealth of Massachusetts, Division of Employment Security, Massachusetts Cities and Towns, Employment in Establishments Subject to Massachusetts Employment Security Law, 1958-66, and addenda for years 1967 and 1968; and State of New Hampshire, Department of Employment Security, Economic Changes in each New Hampshire County, 1947-65, and quarterly data in Employment and Wages in New Hampshire.

a/ Amesbury, Ayer, Boxford, Carlisle, Dunstable, Groton, Littleton, Newbury, Newburyport, Pepperell, Rowley, and Salisbury.

b/ Figure is for 1968.

c/ Change, 1959-68.

d/ Second quarter, 1969.

Table VI

Shifts in Structure of Manufacturing Employment, Merrimack Valley-Southern New Hampshire Study Area

(number of employees)

	Change in Total Manufacturing Employment	Change in Nondurables Manufacturing Employment	Change in Durables Manufacturing Employment
Massachusetts Portion			
Lawrence-Haverhill SMSA (1959-67)	- 200	- 4,000	+ 3,800
Lowell SMSA (1959-67)	- 2,300	- 800	- 1,500
New Hampshire Portion			
Hillsborough County (1959-69)	+ 7,100	- 3,000	+10,100
Merrimack County (1959-69)	+ 1,900	+ 500	+ 1,400
Rockingham County (1959-69)	+ 1,500	+ 300	+ 1,200
Strafford County (1959-69)	+ 1,300	+ 1,600	- 300
Manchester SMSA (1959-67)	- 400	- 2,000	+ 1,600

Sources: See Table V.

they were insufficient to offset job losses in nondurables. The Lowell SMSA suffered losses in both categories.

Significant aspects of the study area's present manufacturing profile are shown in Tables VII to X. The tables were compiled from information on firms published in the Massachusetts Manufacturing Directory for 1969 and the New Hampshire Manufacturing Directory for 1970. Figures for the Lowell area are for cities and towns in the western half of the Massachusetts portion of the study area, and those for the Lawrence-Haverhill area, for cities and towns in the eastern half. The breakdown of data on the New Hampshire portion is in accordance with the State's groupings of municipalities into planning districts.

Table VII shows the distribution of all establishments with 100 or more employees by their location within the study area. The highest centers of concentration are in Lowell, Haverhill, Lawrence, Manchester, Concord, Nashua, and Dover. (Portsmouth would also be included in this group if the nuclear submarine facility were included as a manufacturing activity.) In the Massachusetts portion there is, in addition, dispersion of major manufacturing activity outside the main centers of Lowell, Haverhill, and Lawrence, with only nine of the remaining 25 municipalities failing to have at least one plant with 100 or more employees. In the New Hampshire portion, the Portsmouth and Dover areas show some dispersion of major manufacturing, but in all the other areas, establishments with 100 or more employees tend to be concentrated in their principal cities.

Table VII

Number of Establishments with 100 Employees or More by Location and Employment Size Class, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

City or Town	Employment Size Class			
	100-249	250-499	500-999	1,000 or more
Massachusetts Portion				
Lowell Area				
Ayer	--	--	--	--
Billerica	3	--	--	--
Carlisle	--	--	--	--
Chelmsford	2	1	--	--
Dracut	--	1	--	--
Dunstable	--	--	--	--
Groton	2	--	--	--
Littleton	5	2	--	--
Lowell	19	16	5	1
Pepperell	--	2	--	--
Tewksbury	--	2	--	--
Tyngsborough	--	--	--	--
Westford	1	--	1	--
Lawrence-Haverhill Area				
Amesbury	5	1	1	--
Andover	1	1	2	1
Boxford	--	--	--	--
Georgetown	1	--	--	--
Groveland	--	--	--	--
Haverhill	8	8	1	--
Lawrence	26	11	3	4
Merrimac	--	--	--	--
Methuen	2	--	--	--
Newbury	1	--	--	--
Newburyport	2	1	1	--
North Andover	1	--	1	2
Rowley	--	--	--	--
Salisbury	1	--	--	--
West Newbury	--	--	--	--
New Hampshire Portion				
Manchester Area				
Auburn	--	--	--	--
Bedford	--	--	--	--
Candia	--	--	--	--
Chester	--	--	--	--
Deerfield	--	--	--	--
Derry	--	2	--	--
Dunbarton	--	--	--	--
Goffstown	--	--	--	--
Hooksett	--	1	--	--
Londonderry	--	--	--	--
Manchester	30	15	3	--
New Boston	--	--	--	--
Raymond	--	--	--	--
Weare	--	--	--	--

Table VII (continued)

Number of Establishments with 100 Employees or More by Location and Employment Size Class, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

City or Town	Employment Size Class			
New Hampshire Portion	100-249	250-499	500-999	1,000 or more
Concord Area				
Allenstown	--	--	--	--
Boscawen	--	--	--	--
Bow	1	1	--	--
Canterbury	--	--	--	--
Chichester	--	--	--	--
Concord	7	--	2	--
Epsom	--	--	--	--
Henniker	--	--	--	--
Hopkinton	--	--	--	--
Loudon	--	--	--	--
Northwood	--	--	--	--
Pembroke	--	--	--	--
Pittsfield	1	--	1	--
Warner	--	--	--	--
Webster	--	--	--	--
Nashua-Hudson Area				
Amherst	--	--	--	--
Brookline	--	--	--	--
Hollis	--	--	--	--
Hudson	1	--	--	--
Litchfield	--	--	--	--
Lyndeborough	--	--	--	--
Mason	--	--	--	--
Merrimack	--	2	--	--
Milford	2	--	1	--
Mont Vernon	--	--	--	--
Nashua	11	4	3	5
Pelham	--	--	--	--
Wilton	--	1	--	--
Salem-Plaistow Area				
Atkinson	--	--	--	--
Danville	--	--	--	--
Hampstead	--	--	--	--
Kingston	--	--	--	--
Newton	--	--	--	--
Plaistow	3	1	--	--
Salem	1	--	--	--
Sandown	--	--	--	--
Windham	1	--	--	--
Franklin Area				
Andover	--	--	--	--
Danbury	--	--	--	--
Franklin	1	2	--	--
Hill	--	--	--	--
Northfield	--	--	--	--
Salisbury	--	--	--	--

Table VII (continued)

Number of Establishments with 100 Employees or More by Location and Employment Size Class, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

City or Town	Employment Size Class			
	100-249	250-499	500-999	1,000 or more
New Hampshire Portion				
Portsmouth Area				
Brentwood	--	--	--	--
East Kingston	--	--	--	--
Epping	--	1	--	--
Exeter	2	1	1	--
Fremont	--	--	--	--
Greenland	--	--	--	--
Hampton	--	--	--	--
Hampton Falls	--	--	--	--
Kensington	--	--	--	--
New Castle	--	--	--	--
Newfields	2	--	--	--
Newington	--	--	--	--
North Hampton	--	--	--	--
Portsmouth	4	3	--	--
Rye	--	--	--	--
Seabrook	--	1	1	--
South Hampton	--	--	--	--
Stratham	--	--	--	--
Dover Area				
Barrington	--	--	--	--
Dover	4	2	3	2
Durham	--	--	--	--
Farmington	1	--	--	--
Lee	--	--	--	--
Madbury	--	--	--	--
Middleton	--	--	--	--
Milton	--	--	--	--
New Durham	--	--	--	--
Newmarket	3	--	--	--
Nottingham	--	--	--	--
Rochester	1	1	1	--
Rollinsford	1	--	--	--
Somersworth	1	3	--	1
Strafford	--	--	--	--
Peterborough Area				
Antrim	1	--	--	--
Bennington	1	--	--	--
Deering	--	--	--	--
Francestown	--	--	--	--
Greenfield	--	--	--	--
Greenville	1	--	--	--
Hancock	--	--	--	--
Hillsborough	--	--	1	--
New Ipswich	1	--	--	--
Peterborough	--	--	1	1

Table VII (continued)

Number of Establishments with 100 Employees or More by Location and Employment Size Class, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

City or Town	Employment Size Class			
	100-249	250-499	500-999	1,000 or more
New Hampshire Portion				
Peterborough Area (cont'd)				
Sharon	--	--	--	--
Temple	--	--	--	--
Windsor	--	---	--	--
Claremont Area				
Bradford	--	--	--	--
New London	--	--	--	--
Newbury	--	--	--	--
Sutton	--	--	--	--
Wilmot	--	--	--	--

Sources: Massachusetts Manufacturers Directory, 1969; New Hampshire Department of Resources and Economic Development, Office of Industrial Development, Made in New Hampshire: A Directory of Manufacturers and Manufactured Products, 1970-71.

Note: The Lowell area includes cities and towns in the western half of the Massachusetts portion of the study area, and the Lawrence-Haverhill area, the eastern half. The New Hampshire areas include municipalities in accordance with groupings within the State's planning districts.

In the Lowell and Lawrence-Haverhill areas, the textile, paper, leather, and Printing and publishing industries are still dominant among establishments with 100 employees or more (Table VIII). Even though there has been a substantial shift in each area toward the durable goods industries, the Lowell area is still particularly dependent on the declining textile industry, and the Lawrence-Haverhill area on shoe manufacturing. Moreover, the actual involvement of the Lawrence-Haverhill area in shoe manufacturing or in activities supporting shoe manufacturing is substantially greater than is apparent from an examination of these relatively large plants. Many small family firms continue in the area, particularly in Haverhill, either as manufacturers or as suppliers to the industry (Table IX).

In the New Hampshire portion of the study area, the Manchester and Dover areas are heavily dependent on shoe manufacturing although the Manchester area has shifted toward the electrical machinery, equipment, and supplies industry. The Concord and Nashua-Hudson areas are not dependent on shoe manufacturing and have a generally more diversified industrial structure.

Table X shows the location of large plants--those with 250 or more employees--and their major products.

Table VIII

Number of Establishments with 100 Employees or More, by Major Industries, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

	Massachusetts Portion			New Hampshire Portion						
	Lowell Area	Lawrence-Haverhill Area	Manchester Area	Concord Area	Nashua-Hudson Area	Dover Area	Salem-Plaistow Area	Peterborough Area	Portsmouth Area	Franklin Area
Major nondurable goods industries	36	35	26	6	8	17	3	3	5	2
Textile mill products	17	6	7	--	1	1	1	3	1	1
Apparel and other finished products from fabrics	2	6	6	1	--	--	1	--	--	1
Paper and allied products	4	7	1	--	1	1	--	--	--	--
Leather and leather products	8	14	10	2	3	15	1	--	4	--
Printing and publishing	5	2	2	3	3	--	--	--	--	--
Major durable goods industries	11	14	10	3	6	4	0	3	2	0
Machinery, except electrical	4	3	1	1	4	1	--	2	--	--
Electrical machinery, equipment, and supplies	6	10	9	2	2	3	--	1	2	--
Ordnance and accessories	1	1	--	--	--	--	--	--	--	--

Sources: Massachusetts Manufacturers Directory, 1969; New Hampshire Department of Resources & Economic Development, Office of Industrial Development, Made in New Hampshire: A Directory of Manufacturers and Manufactured Products, 1970-71.

NOTE: See Table VII for cities and towns included in areas.

Table IX

Establishments in the Shoe and Shoe-related Products Industries, by Employment Size Class, Massachusetts Portion of Merrimack Valley-Southern New Hampshire Study Area, 1969 a/

	4-19	20-49	50-99	100-249	250-499	500-999	1,000 or more	Total
Amesbury	--	2	1	2	1	--	--	6
Andover	--	--	--	--	--	1	--	1
Chelmsford	--	1	--	--	--	--	--	1
Georgetown	1	--	--	--	--	--	--	1
Groton	1	--	--	1	--	--	--	2
Haverhill	22	13	12	7	6	1	--	61
Lawrence	5	3	3	6	4	1	1	23
Littleton	--	--	--	1	--	--	--	1
Lowell	5	1	5	6	5	--	--	22
Methuen	--	--	--	1	--	--	--	1
Newburyport	--	1	--	1	--	--	--	2
North Andover	1	1	--	--	--	--	--	2
Pepperell	--	1	--	--	--	--	--	1
Salisbury	--	--	--	1	--	--	--	1

Source: Massachusetts Manufacturers Directory, 1969.

a/ In addition to shoe factories as such, the establishments included are those engaged in tanning, contract stitching, and the manufacturing of shoe dies, patterns, shoe machinery, lasts, soles, toplifts, and heels.

In the Massachusetts portion of the study area, most of the large plants are located in Lowell, Lawrence, and Haverhill, but one or more are located in Westford, Pepperell, Littleton, Chelmsford, Dracut, Tewksbury, Andover, North Andover, Amesbury, and Newburyport (Table X). A high proportion of these large plants are in the textile, shoe, food, and paper industries. However, some are engaged in the more modern segments of the metal, machinery, and electrical products industries. Both the Lowell and Lawrence-Haverhill areas have a very large munitions plant--a space systems and missiles manufacturing establishment in Lowell, and a guided missiles plant in North Andover. A major computer manufacturer has large plants in Lowell and Lawrence. Lowell also has a large radio manufacturing plant, and there is a second computer factory in Tewksbury. The Lawrence area has two very large manufacturers of communications equipment, one in Lawrence and another in North Andover.

In the New Hampshire portion of the study area, there is a concentration of large plants in Manchester, Nashua, and Dover. In addition, one or more such plants are located in Derry, Hooksett, Concord, Pittsfield, Merrimack, Milford, Wilton, Rochester, Somersworth, Portsmouth, Epping, Exeter, Seabrook, Peterborough, Hillsborough, Plaistow, and Franklin. Shoe factories constitute a high proportion of the large plants in the Manchester, Dover, and Portsmouth areas, but in the New Hampshire portion of

Table X

Products Manufactured by Establishments with 250 or More Employees, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

Location of Establishment	Product Manufactured
Massachusetts Portion	
Lowell Area	
Lowell	Commercial Printing
Lowell	Portable phonographs, radios, tape recorders
Lowell	Space systems and missiles
Lowell	Cookies and crackers
Lowell	Commercial Printing
Lowell	Sweaters, knitted cloth
Lowell	Women's footwear
Lowell	Onion rings and frozen fish
Lowell	Misses' and women's shoes
Lowell	Wire and cables
Lowell	Women's shoes
Lowell	Men's dress shirts
Lowell	Computers
Lowell	Upholstery fabrics
Lowell	Knit fabrics
Lowell	Women's shoes
Lowell	Newspaper
Lowell	Non-woven textiles
Lowell	Macaroni and spaghetti
Lowell	High pressure laminates
Lowell	Commercial printing
Lowell	Phonograph cabinets
Westford	Book lithographers
Pepperell	Paper shipping sacks
Pepperell	Kraft specialty papers
Littleton	Concrete
Littleton	Microwave and antenna systems
Chelmsford	Commission wool scouring and combing
Dracut	Woolen textiles
Tewksbury	Fats and fertilizers
Tewksbury	Calculators, computers, and data system components
Lawrence-Haverhill Area	
Lawrence	Woolen and synthetic fabrics and yarn
Lawrence	Women's shoes
Lawrence	Electronic data processing equipment
Lawrence	Diodes, semiconductors
Lawrence	Vinyl sheeting and molded products
Lawrence	Paper shoe cartons
Lawrence	Coated printed paper

Table X (continued)

Products Manufactured by Establishments with 250 or More Employees, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

Location of Establishment	Product Manufactured
Massachusetts Portion	
Lawrence-Haverhill Area	
Lawrence	Paper mill machinery
Lawrence	Women's shoes
Lawrence	Bakery products
Lawrence	Women's shoes
Lawrence	Men's and women's shoes
Lawrence	Wool tops
Lawrence	Plastic laminates
Lawrence	Wigs and hair pieces
Lawrence	Men's and boys' outerwear
Lawrence	Safety devices and controls, plumbing and heating systems
Andover	Guided missiles
Andover	Waterproof and canvas footwear
Andover	Electronic dialing equipment
Andover	Toiletries
North Andover	Woolen goods
North Andover	Microwave and radio transmission systems
North Andover	Textile machinery
Haverhill	Women's shoes
Haverhill	Women's shoes
Haverhill	Boxboard
Haverhill	Canvas products
Haverhill	Women's shoes
Haverhill	Kid and lamb leathers
Haverhill	Women's shoes
Haverhill	Women's shoes
Haverhill	Women's shoes
Amesbury	Metal auto trim parts
Amesbury	Shoes
Newburyport	Silverware
Newburyport	Electric fuses
New Hampshire Portion	
Manchester Area	
Manchester	Tape closures
Manchester	Electrical watt hour meter mountings, electrical heating equipment, electrical fixtures
Manchester	Sweaters
Manchester	Women's shoes
Manchester	Unbleached cotton gauze
Manchester	Women's novelty shoes
Manchester	Women's dress shoes
Manchester	Women's shoes
Manchester	Women's shoes

Table X (continued)

Products Manufactured by Establishments with 250 or More Employees, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

Location of Establishment	Product Manufactured
New Hampshire Portion	
Manchester Area	
Manchester	Panel Meters, aviation instruments, computer components
Manchester	Women's shoes
Manchester	Hosiery finishing
Manchester	Electronic components
Manchester	Aerosol valves
Manchester	Lamps
Manchester	Yarns
Manchester	Bakery products
Manchester	Electronic components switches
Derry	Men's shoes
Derry	Women's shoes
Hooksett	Component parts of jet engines
Concord Area	
Concord	Printing (magazines, catalogues, directories)
Concord	Transistors, tantalum capacitors
Bow	Folding cartons
Pittsfield	Women's shoes
Nashua-Hudson Area	
Nashua	Molded rubber products and custom mixing
Nashua	Greeting cards, social stationery
Nashua	Plastic toys
Nashua	Hybrid integrated circuits, capacitors, and resistors
Nashua	Waterproof footwear, sporting goods, air mattresses
Nashua	Luggage, industrial carrying cases
Nashua	Machinery for pulp and paper industry and plastics industry
Nashua	Paper box folding and gluing machines
Nashua	Men's footwear
Nashua	Converted paper and paper products
Nashua	Electronics systems for industry and defense
Nashua	Shoes
Merrimack	Wood kitchen cabinets, plastic laboratory cabinets, wood louvers
Merrimack	Beer
Milford	Ferrous, nonferrous and steel castings
Wilton	Textile machinery

Table X (continued)

Products Manufactured by Establishments with 250 or More Employees, Merrimack Valley-Southern New Hampshire Study Area, 1969-70

Location of Establishment	Product Manufactured
New Hampshire Portion	
Dover Area	
Dover	Resistors, rheostats, potentiometers and switches
Dover	Automotive interior trim (urethane foam)
Dover	Rotating electrical machinery
Dover	Printing presses, supplementary office equipment
Dover	Women's shoes
Dover	Ladies' shoes
Dover	Cement process shoes
Dover	Women's shoes
Rochester	Women's shoes
Rochester	Electrical measurement devices, watt hour meters, instrument transformers
Somersworth	Bowling shoes, Little League shoes
Somersworth	Women's dress shoes
Somersworth	Women's shoes
Portsmouth Area	
Portsmouth	Processing seafood products
Portsmouth	Women's shoes
Portsmouth	Submarine power and communication cable, insulated wire, plastic pipes and conduits
Epping	Misses', children's cement process shoes
Exeter	Women's cement process novelty shoes
Exeter	Refractory metal coils
Seabrook	Automobile glass run channels and weather strips, light metal stampings
Seabrook	Ladies' shoes
Peterborough Area	
Peterborough	Precision miniature and instrument ball bearings
Peterborough	Digital logic modules, computer memories control panels, cable assemblies
Hillsborough	Semiconductors, diodes and rectifiers
Salem-Plaistow Area	
Plaistow	Fabricated tanks for cyrogenic industry and chemical industry, expansion joints
Franklin Area	
Franklin	Dyeing and finishing woolens
Franklin	Temperature and pressure relief and reducing valves

Sources: Massachusetts Manufacturers Directory, 1969; New Hampshire Department of Resources and Economic Development, Office of Industrial Development, Made in New Hampshire: A Directory of Manufacturers and Manufactured Products, 1970-71.

the study area as a whole, large plants engaging in the industrial machinery, electrical and communications equipment, and electronic components industries are nearly as numerous. By far the largest plant in the area is a 9,000 employee electronic products factory in Nashua. Three major electrical equipment manufacturers have large plants in the area: One company produces electrical instruments in Somersworth and jet engine parts in Hooksett; the second produces electronic components in Nashua and Concord; and the third produces electric lamps in Manchester, high temperature metal coils in Exeter, and semiconductors in Hillsborough. Among other large plants are one in Dover manufacturing urethane foam for automobile interiors, one in Seabrook making metal automobile body parts, and another in Peterborough making precision ball bearings.

Despite the extensive dispersion of manufacturing plants throughout the Merrimack Valley-Southern New Hampshire study area and a considerable diversity in products manufactured, the area is fortunate in having a relative minimum of the types of industrial processes which contribute heavily to air pollution. No oil refineries, blast furnaces, pulp mills, or petrochemical factories are located in the area. The chemicals establishments of the area are mainly quite small firms specializing in the production of materials for dyeing, treating, or finishing textiles and leather, or in the molding and fabrication of

plastic products. One firm has a coal tar dyes plant in Lawrence and a plant producing bleaches and other inorganic chemicals in Merrimack. A major national chemicals manufacturer produces synthetic resins in a plant in Andover, and another produces chemicals specialities in Nashua.

Among the industrial operations which could be of concern in air quality control are plants producing asphalt-based road building materials (Hooksett, Manchester, and Farmington); tires and inner tubes (Manchester); gypsum products (Portsmouth); asbestos products (Billerica); a steel rolling mill (Concord); steel foundries (Milford and Manchester); and gray iron foundries (Amesbury, Lowell, Westford, Brentwood, and Nashua).

PROSPECTIVE POPULATION AND ECONOMIC GROWTH

A recent study conducted for the New Hampshire Department of Resources and Development estimates that population in the New Hampshire portion of the study area will increase from 462,500 in 1966 to 899,000 in 1990. [1/] This estimate implies an average annual growth rate of 2.8 percent, compared to 2.3 percent estimated by the U. S. Census Bureau to have been achieved in the period 1960 to 1966. [2/]

The Central Merrimack Valley Regional Planning District and the Greater Lowell Area Planning Commission have made estimates of 1990 population in the Massachusetts portion of the study area for all cities and towns except Ayer, Carlisle, and Littleton which are not within the jurisdiction of either planning body. [3/]

1/ Anderson-Nicholes & Co., Inc., Public Water Supply Study, Phase One Report, May, 1969.

2/ Computed from figures for the four counties of New Hampshire study area in U. S. Department of Commerce, Bureau of the Census, Estimates of the Population of Counties and Metropolitan Areas, July 1, 1966, Series P-25, No. 427, July 31, 1969.

3/ Central Merrimack Valley Regional Planning District, Population Report, 1968; Greater Lowell Area Planning Commission, Population and Economic Growth, Postwar and Prospective.

These estimates imply an average annual growth rate of 1.9 percent between 1965 and 1990 for the area considered by the two planning agencies. If the rate were applied to the entire Massachusetts portion of the study area, the projected increase in population would be from 434,300 in 1965 to about 695,000 in 1990. The implied annual growth rate of 1.9 percent, based on the separate estimates of the two planning bodies, is substantially in excess of other estimates applicable to the area. For example, the U. S. Census Bureau has estimated alternate annual growth rates for the Boston - Lawrence - Haverhill - Lowell area during the period 1965-75 of 0.4 percent and 0.8 percent. 4/ The National Planning Association projected 1966-80 annual growth rates for the Lawrence-Haverhill and Lowell SMSA's of 1.7 percent and 1.4 percent, respectively. 5/

Whether the population of the study area will grow at the higher rates arrived at by the New Hampshire and Massachusetts studies will depend in part on continued strong economic growth in the Boston area and in part on local sources of growth.

4/ U. S. Department of Commerce, Bureau of the Census, Projections of the Population of Metropolitan Areas, 1975, Series P-25, No. 415, January 31, 1969.

5/ National Planning Association, Economic and Demographic Projections for States and Metropolitan Areas, Regional Economic Projections Series, Report No. 68-R-1, January, 1969.

Economic dependence on Boston appears especially great in the Lowell area. The Greater Lowell Area Planning Commission study points out that the area "has emerged as an important residential bedroom community serving the new industry and service activities of the expanding, diversifying, suburbanizing, integrating Greater Boston Regional Area." The residential bedroom community with jobs in the newer industry of the Boston Region raised per capita income levels in the Lowell area even though manufacturing employment in textiles and leather continued to decline. To serve the enlarged community of higher income residents, the Lowell area has been able to expand employment in construction, trade, services, and government.

In the Lawrence-Haverhill area, the Central Merrimack Valley Regional Planning District officials state that its main out-commuting pattern was established in the 1950's, not to Boston but to Lynn and Salem, by factory workers who found employment to take the place of textile and shoe industry jobs lost in the study area. More recently, however, Andover has experienced a trend similar to that in the Lowell area--the establishment of residences by higher imcome business and professional people who commute to work in Boston but create a local market for trade and other services. Nonmanufacturing employment in Andover has also been substantially increased by its selection as a regional income tax processing center by the Internal Revenue Service.

Southern New Hampshire also appears to be dependent on the vigor of expansion of the Boston Metropolitan area. The authors of the New Hampshire water needs study believe that a substantial portion of recent growth in Southern New Hampshire is the result of "spillover" from Northeastern Massachusetts.

The Lowell and New Hampshire studies anticipate an acceleration of recent in-migration trends. The Lowell area study expects that by 1990, almost half of the labor force residing in the area would commute to outside jobs, mainly toward Boston but in part to Southern New Hampshire. The New Hampshire study expects that by 2020, the spillover from Massachusetts will contribute 50 to 60 percent of the State's annual growth in population, with the growth largely in Rockingham and Hillsborough Counties.

Thus, the Boston area's ability to sustain economic growth will be of critical importance to population expansion in the study area. This prospect is clouded by the high dependence of its research and development-based industries on changing needs of the national defense and space programs.

There are similar uncertainties with respect to a significant portion of the study area's own sources of employment. A five-year phase-out of nuclear submarine construction at the Portsmouth Naval Shipyard, affecting some 8,000 military and civilian employees, is now underway. Employment at the Pease Air Force Base, ordnance manufacturing in Lowell and Andover,

and the military portion of the machinery, electrical products, and electronic components industries located throughout the study area are also vulnerable to changes in defense requirements. Unemployment data available on SMSA's suggest that the Massachusetts portion of the study area may be especially vulnerable to cutbacks in military and space expenditures (Figure 10).

Future electric power requirements by the study area will be met in the future as at present largely through the New England regional production and distribution pool. While no additional generating stations are planned within the study area, a 465-megawatt conventional steam generating unit will be added in 1972 to an existing station in Salem which is just southeast of the Massachusetts portion of the study area. The fuel to be used in the new unit is not indicated. However, coal is the principal fuel used in the units now in operation.

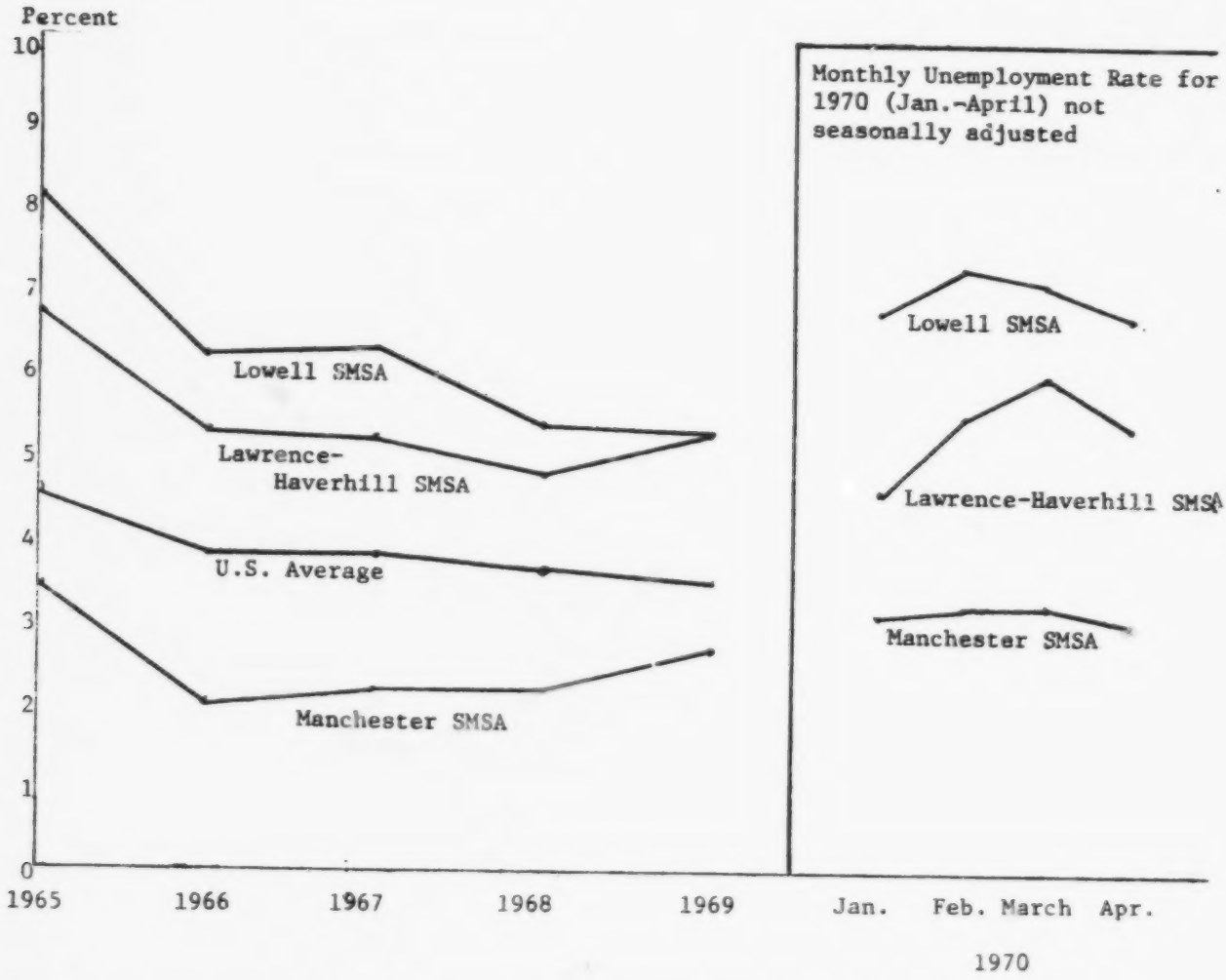

FIGURE 10- Unemployment Rates, Lawrence-Haverhill, Lowell, and Manchester SMSA's, 1965-1970

Sources: U.S. Department of Labor, Manpower Report of the President April 1968. and Area Trends in Employment and Unemployment, March and April, 1970; unpublished monthly data for March and April, 1970, obtained from the Department of Labor.

PROBABLE DIRECTIONS OF URBAN GROWTH

Assuming that economic diversification will continue and that population growth will be vigorous, the New Hampshire and Massachusetts studies expect a general accentuation of the present directions of urban development in the study area. The New Hampshire study expects that people and industries seeking lower densities and more open space will continue to move from Massachusetts into Hillsborough and Rockingham Counties. Merrimack County is expected to grow because of urban expansion around the State Capitol at Concord, while Strafford County's growth will be based on local manufacturing and development of recreational resources. In Massachusetts, both locally-supported population growth and an increased resident labor force commuting to work outside the study area are expected. The resulting projected population distribution in cities and towns by 1990 is shown in Figure 11. The "U"-shaped pattern which emerges is not essentially different in shape or direction from the pattern of urban development which exists at the present time.

The present system of interstate and other express highways, completed or under construction, would tend to reinforce the present and expected directions of development (Figure 12). The Everett Turnpike and I-93 maintain close connections between the Lowell and Lawrence areas via Nashua and Derry, respectively,

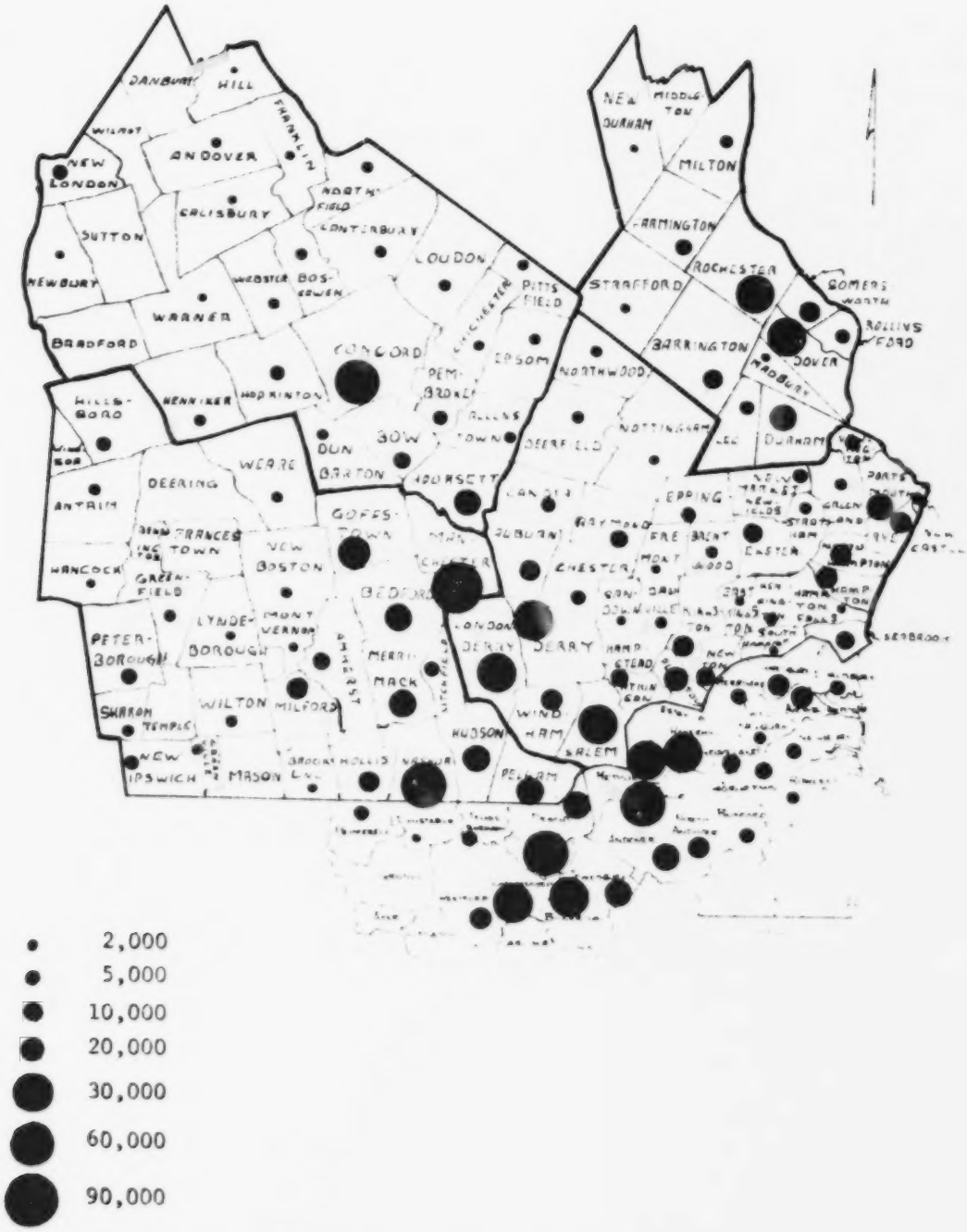

FIGURE 11 - Estimated 1990 Population of Cities and Towns, Merrimack Valley-Southern New Hampshire Study Area

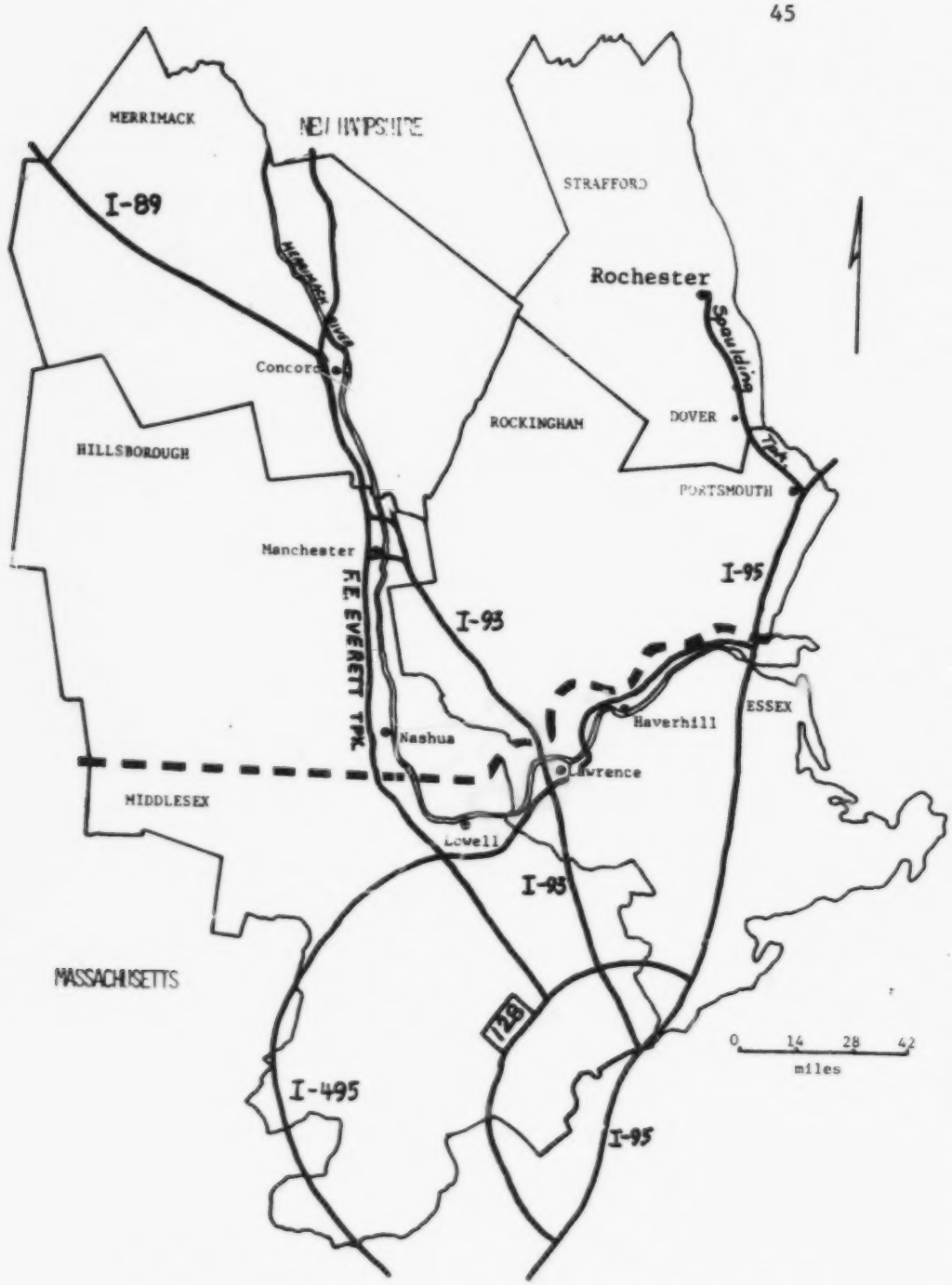

FIGURE 12 - Major Expressways in Present Highway System of Merrimack Valley-Southern New Hampshire Study Area

to Manchester and Concord. Completion of the New Hampshire portion of I-95 will strengthen links between the Rochester-Dover area through Portsmouth with the lower Merrimack Valley area. The three major north-south highway routes are tied together by the recently completed I-495. This expressway also brings Lawrence and Lowell closer together, and both areas hope for industrial development along I-495 of the kind which occurred earlier on Route 128 nearer Boston.

REGIONAL GOVERNMENTAL ORGANIZATION

State Planning Districts

The largest geographical regional units in the Merrimack Valley-Southern New Hampshire study area are the State planning districts. In response to a September, 1967, Presidential memo which encouraged the establishment of uniform planning and development districts, both States in the study area began to delineate state planning districts. Massachusetts proposed tentative planning districts over a year ago, but these are presently being redrawn to define more viable units for health, education, welfare, and planning purposes.

In December, 1968, the Governor's Regional Planning Committee accepted a proposal that divided New Hampshire into 17 planning regions. Nine planning districts are either totally or partially contained within the Southern New Hampshire portion of the study area (Figure 13). The report prepared by the Regional Planning Committee noted the dilemma which existing intercommunity cooperation had created for communities which found themselves in a multitude of regional relationships with community groups of varying composition.

In delineating the planning region boundaries, the Committee employed two major procedures: 1) existing regional groupings were examined, and 2) the potential for urban activity of each

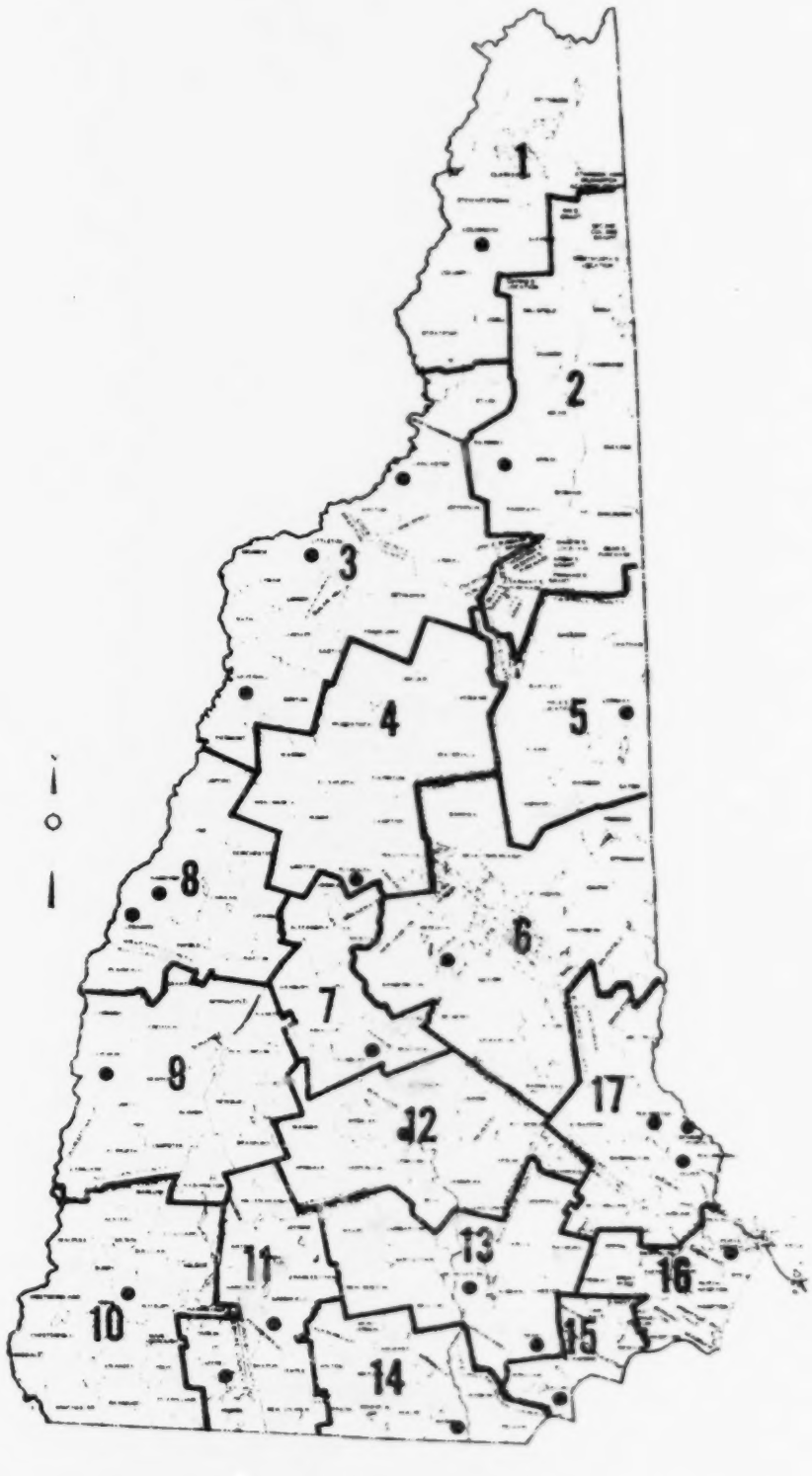

FIGURE 13 - New Hampshire State Planning Districts as Accepted by the Governor's Regional Planning Committee, December 6, 1968.

community was measured. Inter-community linkages were superimposed upon these factors, and the most logical regions for purposes of planning were delineated. (See Table XI.)

Regional Planning Bodies

There is one council of governments and six regional planning commissions in the Central Merrimack Valley-Southern New Hampshire study area. Two of the regional planning bodies are in the Massachusetts portion of the study area, while the remaining five are within New Hampshire.

Northern Middlesex Area Commission (NMAC). The Northern Middlesex Area Commission was formed in 1966 as the Greater Lowell Planning Commission. Its planning area consists of the municipalities within Middlesex County comprising the Lowell SMSA and the towns of Dunstable and Pepperell. Having completed comprehensive planning studies, NMAC is presently entering the plan formulation and action phase of a Master Plan for the area. Its newest projects deal with housing, law enforcement and criminal justice planning, solid waste disposal planning, and conservation.

Central Merrimack Valley Regional Planning District Commission (CMVRPDC). The Central Merrimack Valley Regional Planning District Commission, established in 1959, is the one council of governments in the study area. CMVRPDC has planning responsibility for all of the cities and towns in the Massachusetts portion of the Lawrence-

Table XI

Cities and Towns in New Hampshire State Planning Districts Within the Merrimack Valley-Southern New Hampshire Study Area

Planning Region 12:
Concord Area

Concord
Allenstown
Boscawen
Bow
Canterbury
Chichester
Epsom
Henniker
Hopkinton
Loudon
Northwood
Pembroke
Pittsfield
Warner
Webster

Planning Region 13:
Manchester Area

Manchester
Auburn
Bedford
Candia
Chester
Deerfield
Derry
Dunbarton
Goffstown
Hooksett
Londonderry
New Boston
Raymond
Weare

Planning Region 14:
Nashua-Hudson Area

Nashua
Hudson
Amherst
Brookline
Hollis
Litchfield
Lyndeborough
Mason
Merrimack
Milford
Mont Vernon
Pelham
Wilton

Planning Region 15:
Salem-Plaistow Area

Salem
Plaistow
Atkinson
Danville
Hampstead
Kingston
Newton
Sandown
Windham

Table XI (continued)

Cities and Towns in New Hampshire State Planning Districts Within the Merrimack Valley-Southern New Hampshire Study Area

Planning Region 16:
Portsmouth Area

Portsmouth
Brentwood
East Kingston
Epping
Exeter
Fremont
Greenland
Hampton
Hampton Falls
Kensington
New Castle
Newfields
Newington
North Hampton
Rye
Seabrook
South Hampton
Stratham

Planning Region 17:
Dover Area

Dover
Barrington
Durham
Farmington
Lee
Madbury
Middleton
Milton
New Durham
Newmarket
Nottingham
Rochester
Rollinsford
Somersworth
Strafford

Planning Region 7:
Franklin Area

Cities and towns within study area:

Andover
Danbury
Franklin
Hill
Northfield
Salisbury

Cities and towns outside of study area:

Alexandria
Bridgewater
Bristol
Hebron
Tilton

Table XI (continued)

Cities and Towns in New Hampshire State Planning Districts Within the Merrimack Valley-Southern New Hampshire Study Area

Planning Region 9:
Claremont Area

Cities and towns within study area:

Bradford
New London
Newbury
Sutton
Wilmot

Cities and towns outside of study area:

Claremont
Acworth
Charlestown
Cornish
Craydon
Goshen
Grantham
Langdom
Lempster
Newport
Springfield
Sunapec
Unity
Washington

Planning Region 11:
Peterborough Area

Cities and towns within study area:

Peterborough
Antrim
Bennington
Deering
Francestown
Greenfield
Greenville
Hancock
Hillsborough
New Ipswich
Sharon
Temple
Windsor

Cities and towns outside of study area:

Dublin
Jaffrey
Rindge

Haverhill SMSA plus the town of Boxford. All of these municipalities are located within Essex County. The Commission's principal programs at present include interagency coordination, service to local groups, and water and sewer planning.

Southern New Hampshire Planning Commission. Formed in 1966, the Southern New Hampshire Planning Commission has planning responsibility for the four cities and towns in the Manchester SMSA, and for two additional towns--Auburn and Londonderry. All of the municipalities are within Hillsborough County. While the Commission's major areas of concern at present are housing and solid waste disposal, they are also actively engaged in planning related to water and sewer facilities, community shelter and local planning programs.

Central New Hampshire Planning Commission. The Central New Hampshire Planning Commission has planning jurisdiction for fifteen municipalities surrounding the City of Concord. The newly formed Commission is concentrating its efforts on the development of a work program which would give priority to two projects: 1) a technical services program to localities, and 2) the basic planning necessary to meet planning requirements under various Federal capital grant programs.

Nashua-Hudson Regional Planning Commission. The Nashua-Hudson Regional Planning Commission comprises the City of Nashua and seven other towns, all of which are in Hillsborough County.

The Commission's principal program at present deals with sanitary waste disposal.

Salem Regional Planning Commission. The Salem Regional Planning Commission has planning responsibility for all of the cities and towns in the state planning district in which it is located, except for the town of Hampstead. The Commission, which is in the initial stages of organization, foresees that its first undertaking will be a housing facilities study.

Strafford Regional Planning Commission. The Strafford Regional Planning Commission has planning responsibility for the cities and towns within Strafford County and a few neighboring towns in Rockingham County. The area coincides with the sub-state planning region in which the City of Dover is located. The Commission's present activities are primarily the preparation of a comprehensive plan, although some attention is being given to the programming of water and sewer facilities.

Metropolitan Clearinghouses

In accordance with the Intergovernmental Cooperation Act of 1968, three regional planning bodies in the study area have been designated as metropolitan clearinghouses--the Northern Middlesex Area Commission, the Central Merrimack Valley Regional Planning District Commission and Southern New Hampshire Planning Commission.

Through the clearinghouses, Federal development assistance is coordinated with State, regional and local comprehensive planning. As clearinghouses, each of the three agencies is responsible for review of project proposals and applications for Federal assistance submitted by the localities within their respective planning jurisdictions.

Air Pollution Control Organizations

Both States in the study area have established State organizations responsible for air pollution control. In Massachusetts, this agency is the Bureau of Air Use Management of the Department of Health. The Bureau has an anticipated 1971 budget of $595,000, $375,000 of which is attributable to Federal funds. Its 1971 staff is expected to consist of 24 persons.

The Massachusetts Bureau of Air Management has designed and is presently implementing six regional air pollution control district programs which will function with assistance from and under the administration of the overall statewide program. One of the districts proposed by the Bureau is in the Central Merrimack Valley portion of the study area. This district--the Merrimack Valley Air Pollution Control District--would encompass all of the cities and towns in the Massachusetts portion of the study area (Figure 14). The Merrimack Valley program has a 1971 anticipated budget of $70,000, with $50,000 in Federal funds and $20,000 in State and local funds. The District's proposed staff would be five.

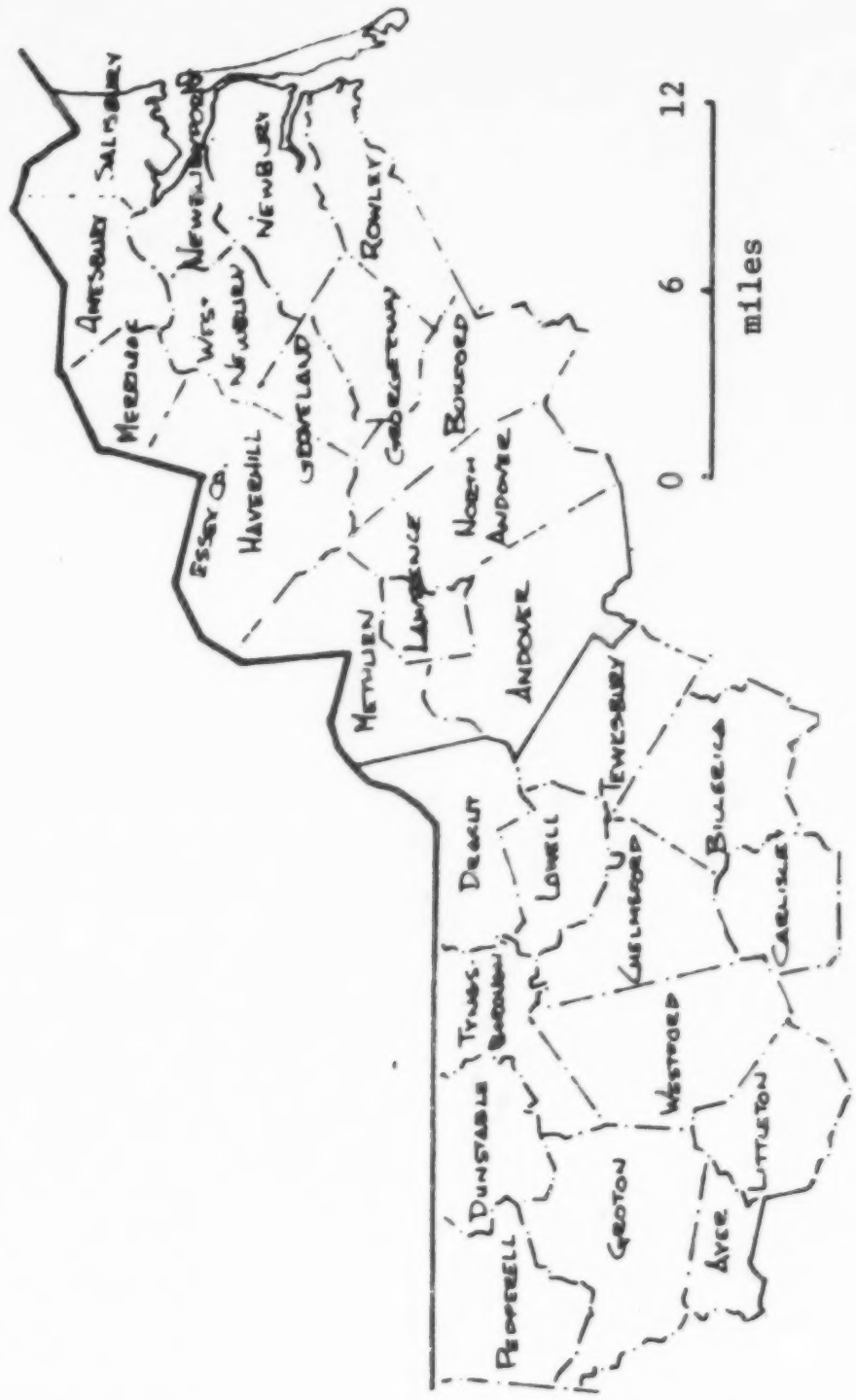

FIGURE 14 - Proposed Merrimack Valley Air Pollution Control District, State of Massachusetts

The legislation by which the Bureau is authorized to establish air pollution control districts states that such districts must be compatible with any air quality region that might be designated by the Department of Health, Education, and Welfare under the provisions of the Air Quality Act of 1967, as amended.

In New Hampshire, air quality control is the responsibility of the New Hampshire Air Pollution Control Commission and its operating body, the New Hampshire Air Quality Control Agency. The Commission's budget for fiscal year 1970 is $66,000 with $32,000 attributable to Federal funds and $34,000 attributable to non-Federal funds. No changes in the budget are foreseen for fiscal year 1971. Agency personnel include a part-time director, a chemist and four technicians.

EVALUATION OF TECHNICAL FACTORS

The boundaries of an air quality control region should be designed to include both sources of air pollution and people and property affected by those sources. In examining the technical factors of importance, then, it is necessary to consider (a) the total quantity of pollutants emitted, (b) the geographic pattern of emission sources, and (c) patterns of pollutant dispersion.

In the Merrimack Valley area, information with respect to these factors was obtained from an emission inventory conducted by the National Air Pollution Control Administration (NAPCA), a report, "Pollution Control and Management," prepared for the New England Regional Commission, air quality data obtained locally, and a theoretical estimate of air quality from a diffusion model.

THE EMISSION INVENTORY

The emission inventory, based on 1968 data, included the study area shown in Figure 15, which encompassed six counties in New Hampshire and twenty-eight cities and towns in two counties of Massachusetts. The NAPCA emission inventory, which estimated emissions of five major pollutants (sulfur oxides, particulates, carbon monoxide, hydrocarbons, and

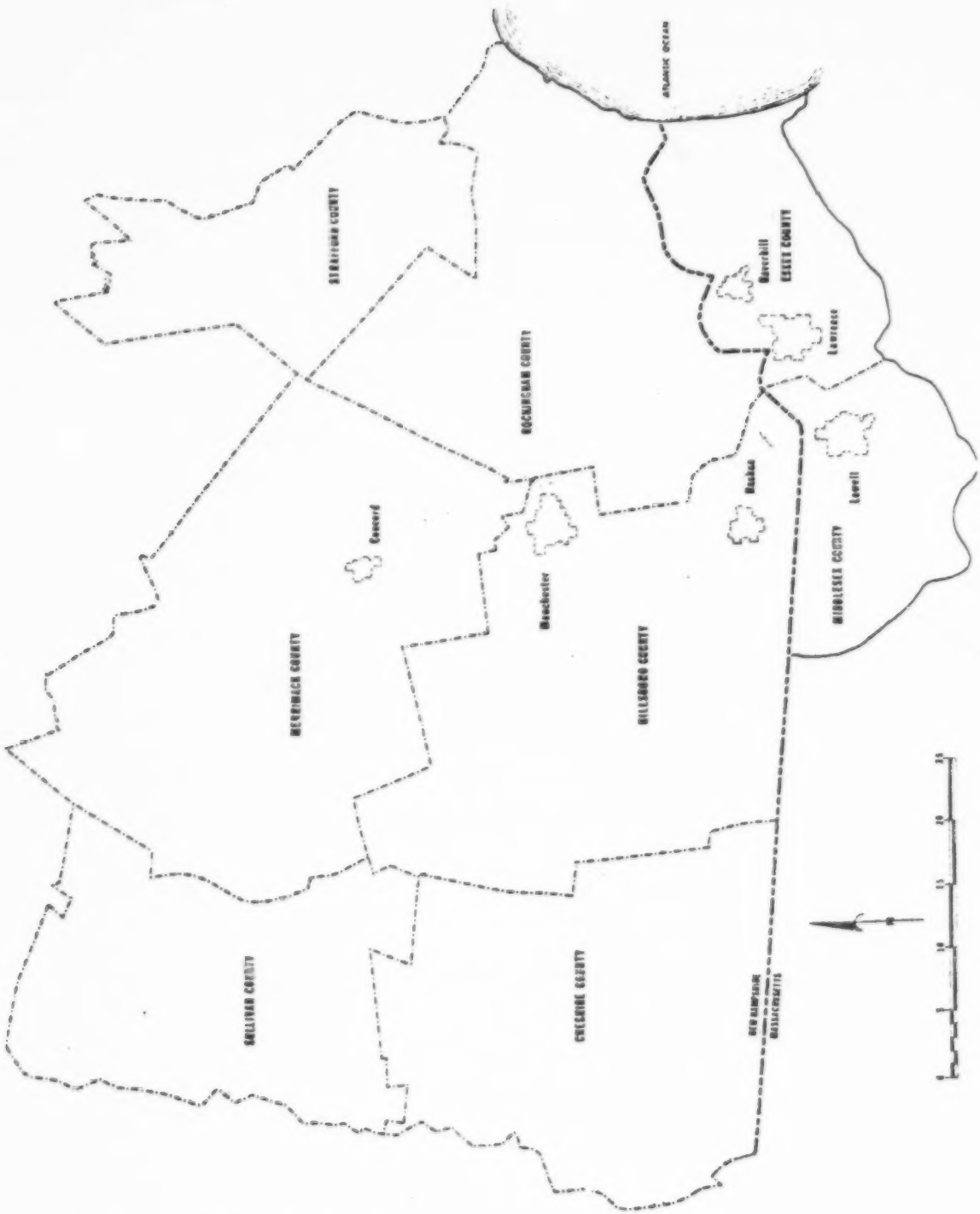

FIGURE 15 - Merrimack Valley Metropolitan Area

nitrogen oxides) is available in more complete form as a separate NAPCA publication. This chapter will summarize the data from that report.

The volume of pollutants in the Merrimack Valley area was estimated by NAPCA individually for major point sources and areawide for other sources through a survey technique developed by the Public Health Service. 6/ Major point sources in the area included individual sources with more than 0.50 tons per day emissions of any pollutant, and were generally categorized as power plant, industrial, solid waste, or airports. Area sources included motor vehicles, residential fuel users, small commercial and industrial facilities, and on-site refuse burning equipment.

Emission estimates were generally derived by applying average emissions factors 7/ to indicators of pollutant emissions such as fuel type, consumption rates, and production data.

By combining emission estimates for major point sources with areawide source estimates, the total estimated volume in tons per year of each pollutant was obtained. Figures 16 and 17 show these estimated totals by volume and percentage shares of each category of pollution source.

6/ Public Health Service, Rapid Survey Technique for Estimating Community Air Pollution Emissions. Publication No. 999-AP-29, Environmental Health Series, U.S.D.H.E.W., Division of Air Pollution, Cincinnati, Ohio, 1966.

7/ Public Health Service, Compilation of Air Pollutant Emission Factors. Publication No. 999-AP-42, Environmental Health Series, U.S.D.H.E.W., NAPCA, Durham, North Carolina.

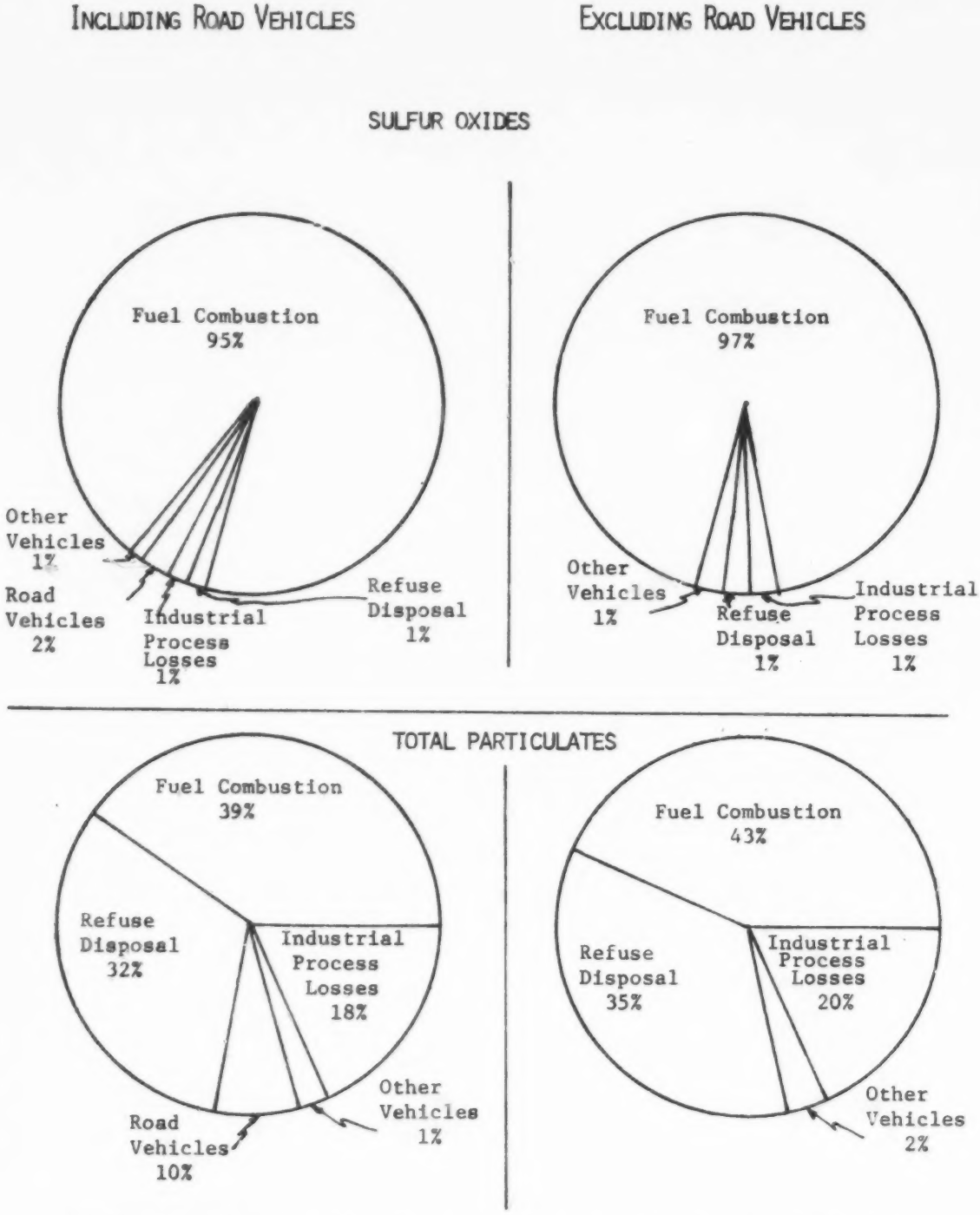

FIGURE 16 - Estimated Distribution of Emissions by Source, Inclusive and Exclusive of Road Vehicles, Merrimack Valley Metropolitan Area, 1968

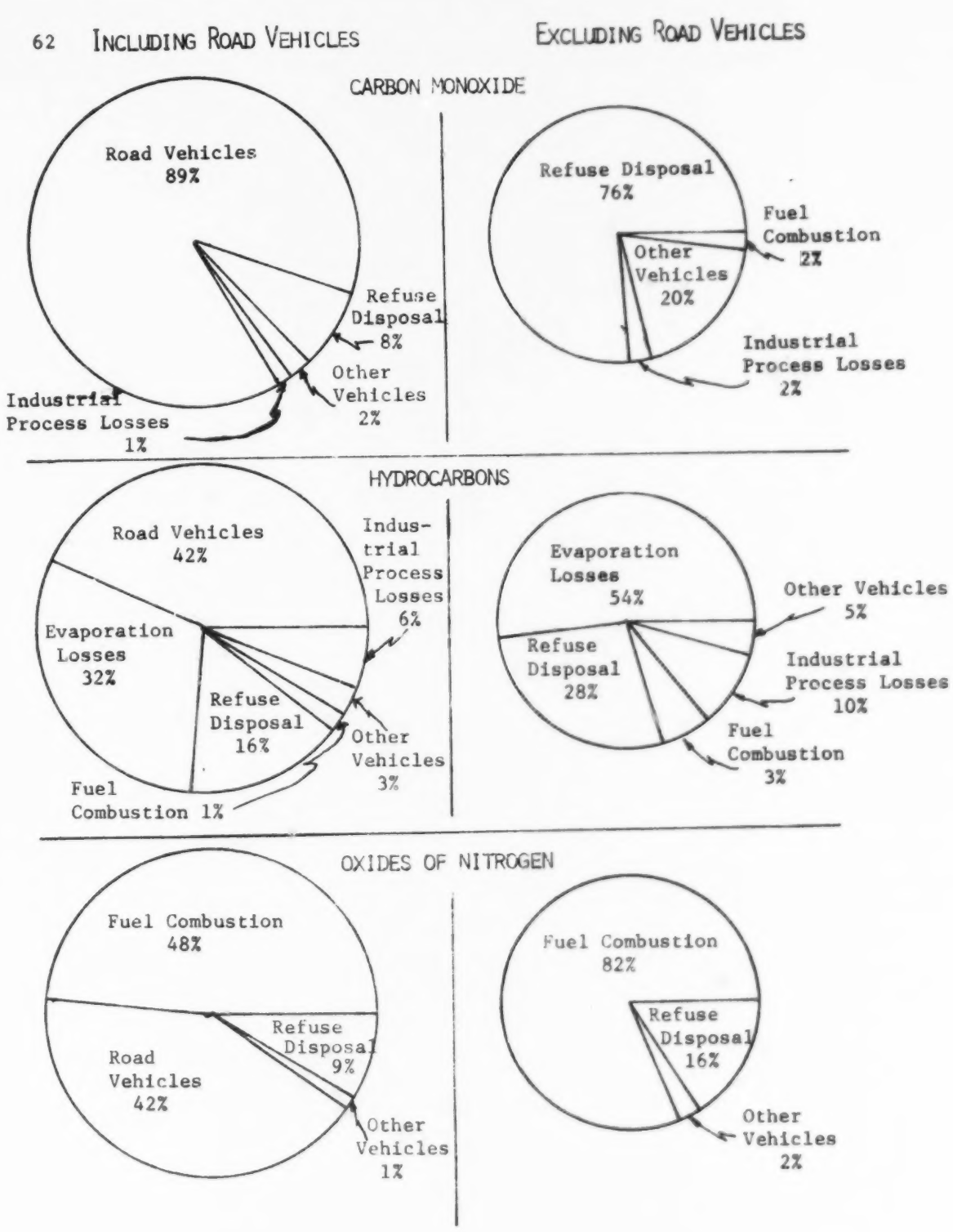

FIGURE 16 (continued) - Estimated Distribution of Emissions by Source, Inclusive and Exclusive of Road Vehicles, Merrimack Valley Metropolitan Area, 1968

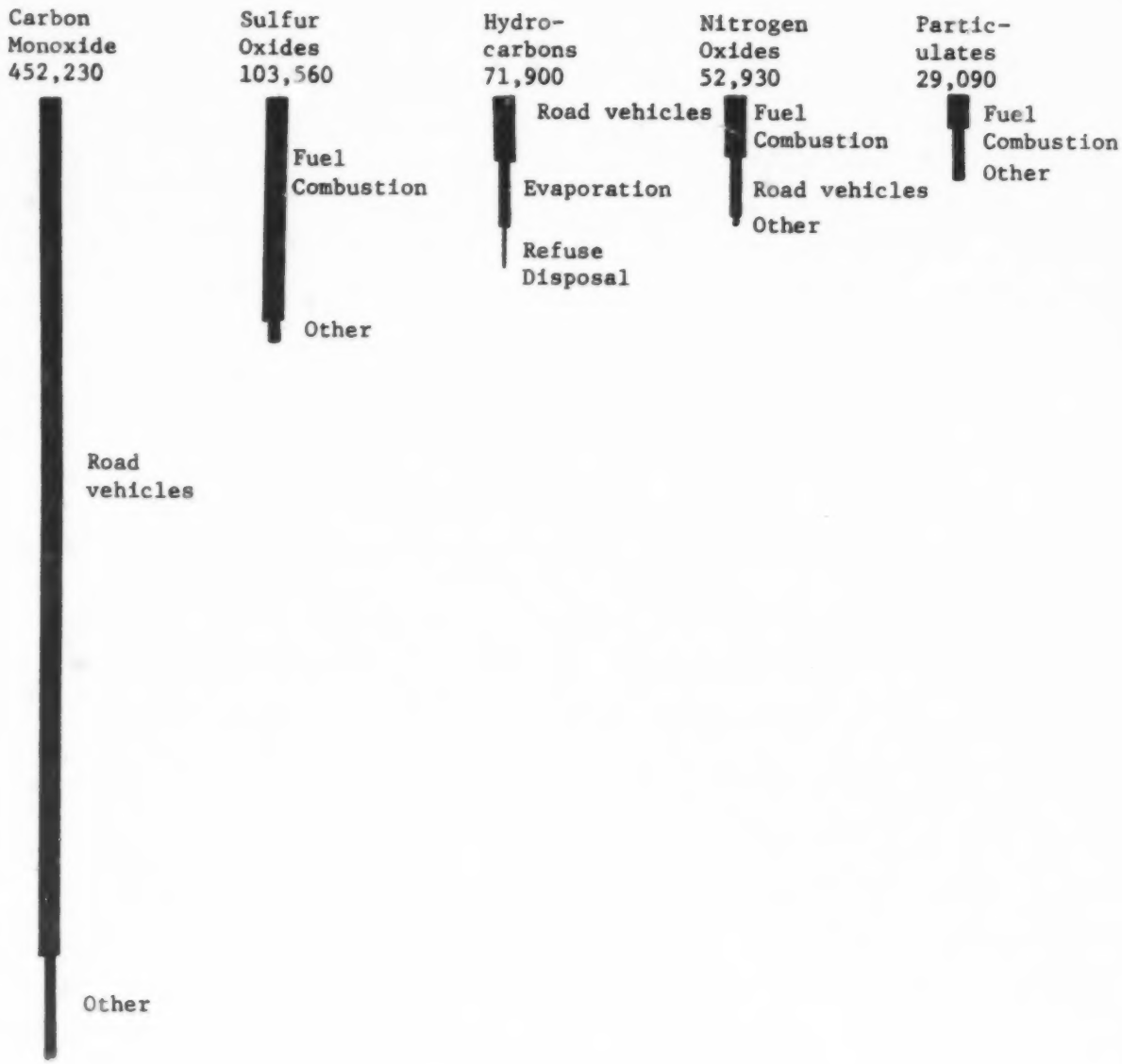

FIGURE 17 - Air Pollution Emissions in the Merrimack Valley Metropolitan Area, 1968 (tons per year)

The geographic pattern of these emissions was determined by distributing emissions among grid zones as shown in Figure 18. Point sources are located on the grid zones in Figure 18-a, and estimated emissions from point sources were attributed to the grids of their location (Table XII). Point and area sources were combined and the total emissions distributed among the New Hampshire counties and the Massachusetts portion of the study area (Table XIII). The percentage contribution of each county to total air pollution emission is shown in Table XIV. Emission density variations per square mile were also plotted for the various grid zones (Figures 19,20, 21, 22, 23).

Examination of these data shows the following:

1. Sulfur oxides are predominantly generated by the combustion of fuels. The principal source (over 65 percent) is fossil fueled electric generating plants.
2. Particulate matter is emitted largely from stationary fuel combustion and solid waste disposal operations.
3. Carbon monoxide arises from the operation of motor vehicles principally, with solid waste operations also contributing.
4. Hydrocarbons are emitted chiefly as a result of motor vehicle operation and fueling, including both fuel consumption and evaporative losses.
5. Oxides of nitrogen are emitted principally from motor vehicle operations and steam-electric power generation.

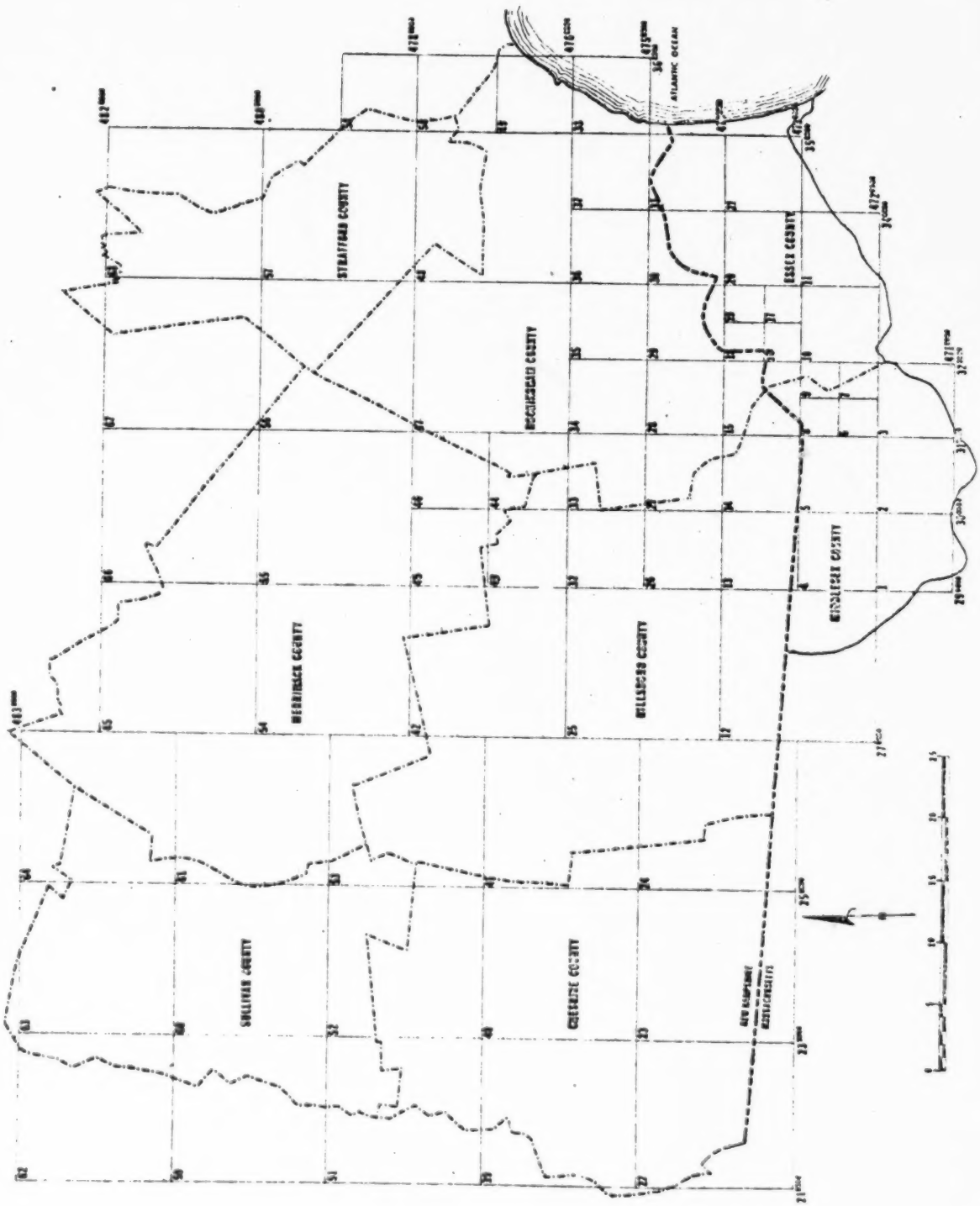

FIGURE 18 - Merrimack Valley Metropolitan Area Grid Coordinate System

FIGURE 18-a - Pollution Source Locations in the Merrimack Valley Metropolitan Area

Table XII

Summary of Air Pollutant Emissions from Point Sources in Tons/Day for the Merrimack Valley Metropolitan Area, 1968

Grid	Sulfur Oxides	Parti-culates	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
3	0.0	0.54	2.91	1.02	0.37
3	0.0	0.00	1.41	0.26	0.06
5	0.7	0.04	0.00	0.00	0.14
5	0.0	0.65	3.49	1.23	0.45
5	0.0	0.87	4.65	1.64	0.60
5	0.1	1.63	0.09	0.02	0.19
8	0.0	0.39	2.09	0.73	0.27
10	1.5	0.09	0.00	0.00	0.29
10	2.9	8.17	1.94	0.01	0.55
10	0.0	0.43	2.32	0.82	0.30
10	0.2	1.86	0.10	0.03	0.21
12	2.0	4.27	0.08	0.02	0.53
13	0.1	0.71	0.00	0.00	0.03
13	1.2	0.08	0.00	0.00	0.25
13	0.2	0.01	0.00	11.00	0.04
13	0.0	0.77	0.00	0.00	0.01
13	0.0	4.09	0.00	0.55	0.00
15	0.0	0.00	0.11	0.02	0.00
16	1.8	0.11	0.01	0.01	0.36
16	2.7	0.17	0.01	0.01	0.54
16	2.8	0.18	0.01	0.01	0.56
16	0.0	0.98	5.23	1.84	0.67
17	0.0	0.05	11.34	2.14	0.53
20	0.0	0.00	1.64	0.31	0.07
26	0.7	0.04	0.00	0.00	0.14
31	0.0	0.00	0.29	0.05	0.01
33	0.0	0.16	11.70	2.23	0.61
43	0.1	1.63	0.09	0.02	0.19
45	0.5	0.03	0.00	0.00	0.10
45	2.0	0.05	0.00	0.01	0.59
45	2.5	0.07	0.00	0.02	0.74
50	28.1	0.80	0.00	0.25	8.37
50	3.0	0.08	0.00	0.02	0.89
54	0.8	0.05	0.00	0.00	0.18
55	0.7	0.04	0.00	0.00	0.14
55	1.3	0.09	0.00	0.00	0.28
55	148.8	16.09	0.75	0.30	30.13
59	0.6	0.04	0.00	0.00	0.12

Table XIII

Air Pollutant Emissions in the Merrimack Valley-Southern New Hampshire Study Area, by Emissions Sources and by County, 1968
(tons per year)

		Fuel Combustion								
	County	Industrial	Institutional	Residential	Power Plants	Total, Fuel Combustion	Industrial Process Losses	Transportation	Refuse Disposal	Grand Total
Particulates	Massachusetts portion	2,154	1,004	550	0	3,709	2,832	1,332	4,954	12,827
	Hillsborough	162	109	307	47	627	2,297	599	1,834	5,357
	Merrimack	39	256	100	5,873	6,270	0	231	442	6,943
	Rockingham	41	53	185	325	606	0	346	1,499	2,451
	Strafford	16	49	96	0	163	0	201	340	704
Sulfur Oxides	Massachusetts portion	7,615	13,189	1,939	0	22,745	80	773	489	24,087
	Hillsborough	2,231	1,076	1,134	1,652	6,096	0	352	202	6,650
	Merrimack	471	1,122	379	54,340	56,314	0	150	37	56,501
	Rockingham	374	427	693	11,385	12,881	0	289	123	13,293
	Strafford	223	580	374	0	1,178	0	131	33	1,347
Carbon Monoxide	Massachusetts portion	77	95	123	0	295	700	167,603	18,894	187,492
	Hillsborough	14	11	71	0	98	0	88,975	6,257	95,330
	Merrimack	3	137	23	275	439	0	35,961	2,284	38,684
	Rockingham	2	6	43	1	54	0	53,655	7,767	61,476
	Strafford	1	4	23	0	30	0	31,710	1,733	33,473

Table XIV

Percentage Contribution of Each County
to Total Air Pollutant Emissions

County	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Mass. Portion	24	45	45	43	36
Hillsborough	7	19	23	27	15
Merrimack	55	25	9	8	28
Rockingham	13	9	15	15	16
Strafford	1	2	8	7	5

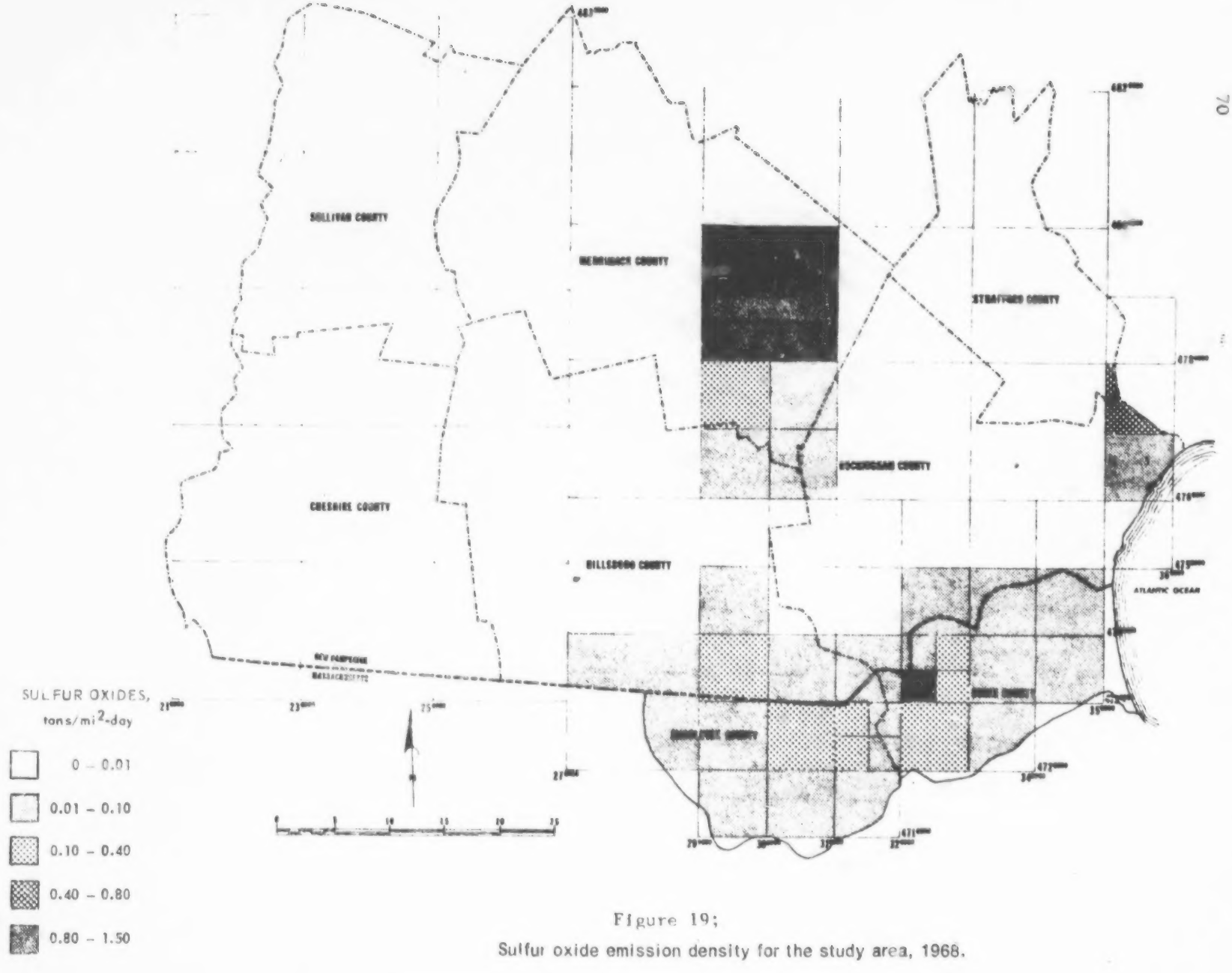

Figure 19;
Sulfur oxide emission density for the study area, 1968.

Figure 20;

Particulate emission density for the study area, 1968.

Figure 21;

Carbon monoxide emission density for the study area, 1968.

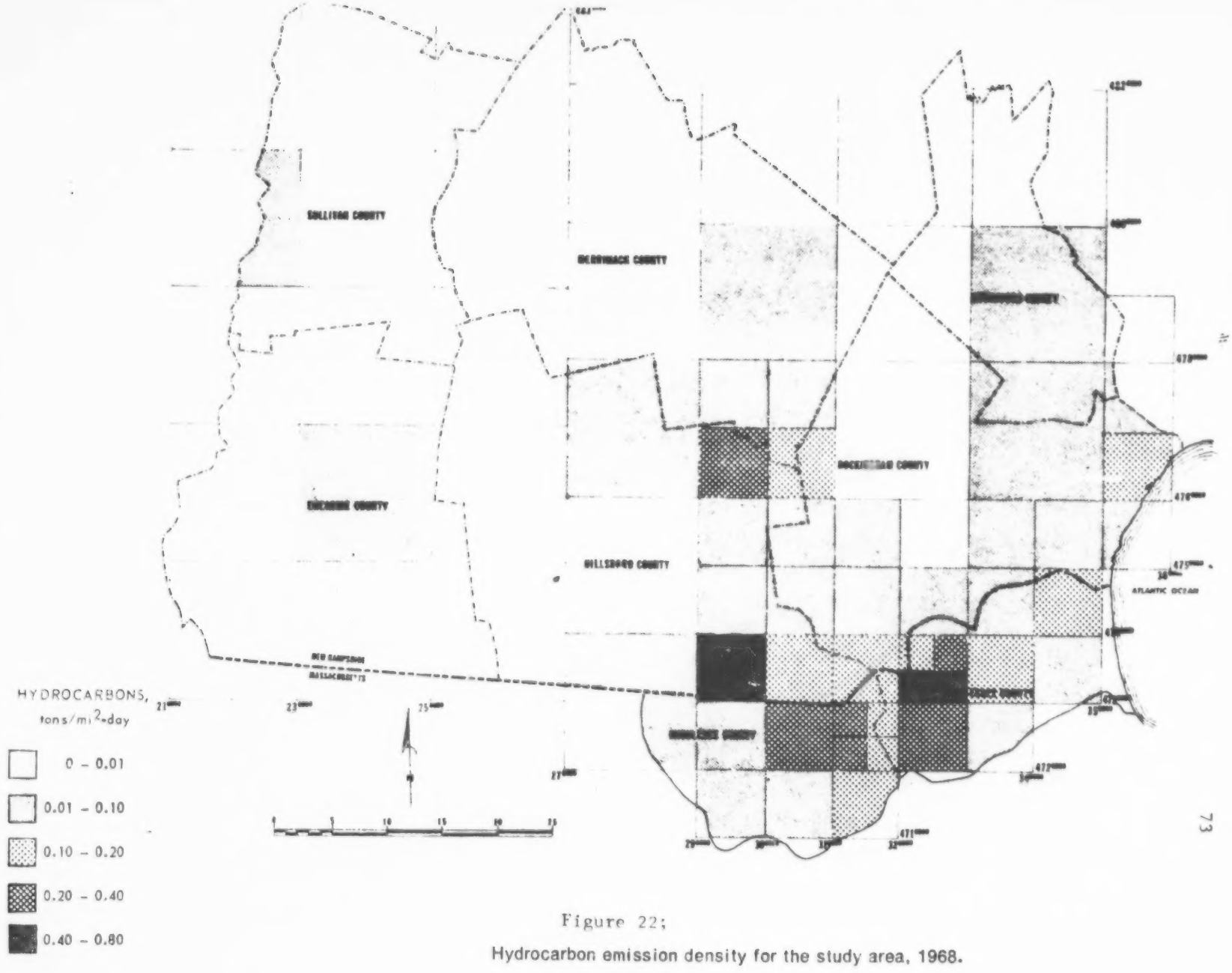

Figure 22;

Hydrocarbon emission density for the study area, 1968.

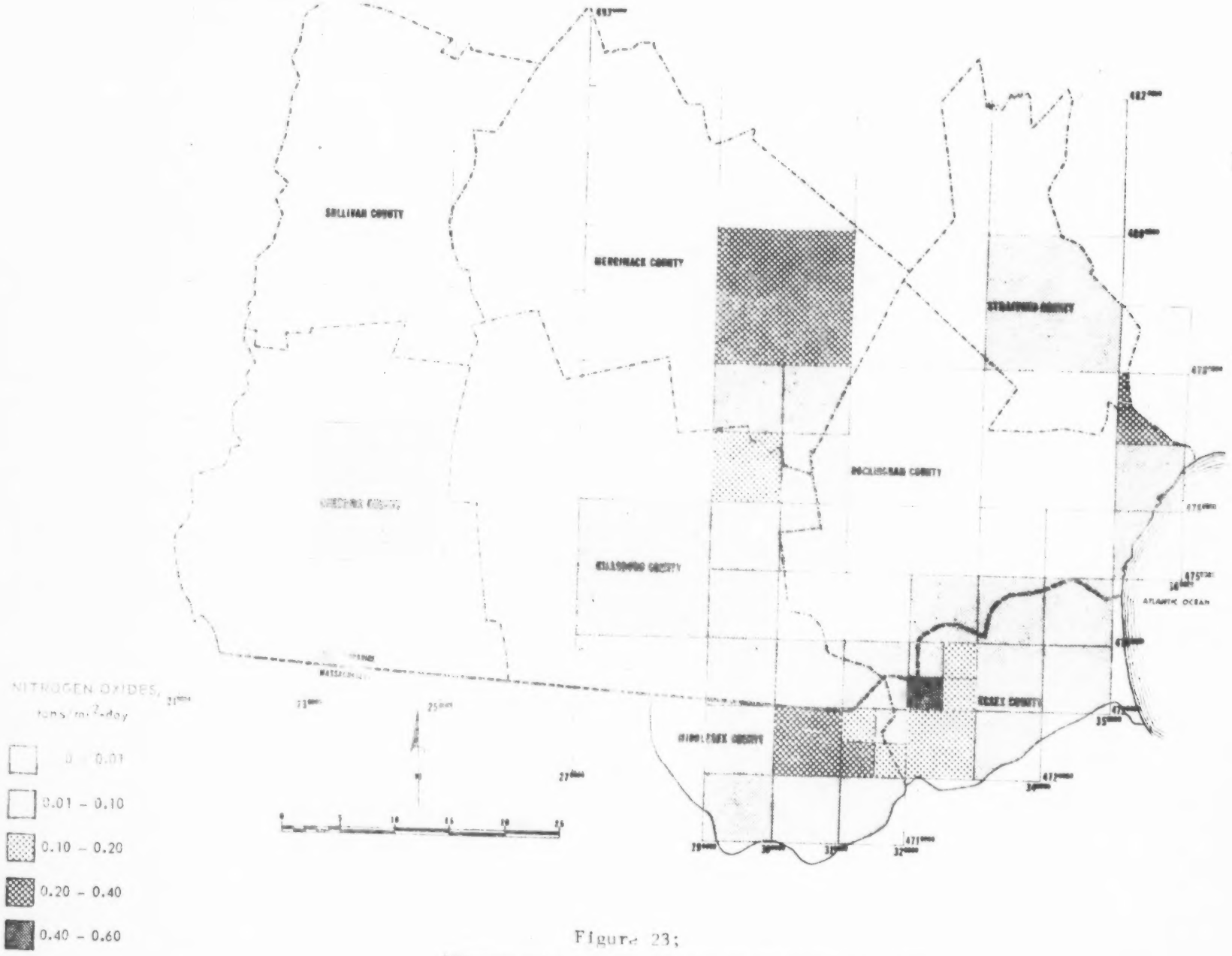

Figure 23;
Nitrogen oxide emission density for the study area, 1968.

The distribution of these pollutants shows a strong relationship to the degree of urbanization of the study area, with the greatest estimated emissions occurring in the Massachusetts portion and parts of Hillsborough and Merrimack Counties, New Hampshire. Emissions attributable principally to motor vehicle operation follow the same general pattern as those from stationary sources, as the highway system generally follows the urbanized areas.

In evaluating the emission inve..tory, some discussion of patterns of fuel usage is helpful. While all three of the major fuels (coal, oil, and natural gas) are consumed in the study area, fuel oil is the most important. In this respect, the study area is typical of the New England region generally. Residual fuel oil, with sulfur content in the range of 1.6 to 2.3 percent, is burned in steam-electric utilities and commercial-industrial installations. Distillate oil, with sulfur content of 0.2 to 1.5 percent, is the predominant residential and commercial heating fuel. Coal is used as fuel principally in the Merrimack generating plant, in Hillsborough County. A limited amount of natural gas is used principally for residential space heating.

The electric power industry in New England has changed dramatically over the years. As late as 1920, about 35 percent of the power was produced by hydro-electric plants, but this

has steadily declined to less than 10 percent today. Thus, most of the electric energy generated is of thermal origin, using residual oil imported principally from Venezuela and the West Indies. Coal used in the region is imported principally from Virginia and West Virginia. Because imported residual oils are increasingly price competitive with coal, generating stations have been switching to residual oil. One result reported in the study,"Pollution Control and Management", prepared for the New England Regional Commission, is "...a switch from coal to oil would increase the heat rate (drop the conversion efficiency) by several percent. This would mean that sulfur emissions per kilowatt hour produced would be slightly greater for fuel oil than for coal." Because New England generally, and the study area particularly, have to import all fuels and incur substantial transportation costs, there is considerable interest in the development of nuclear generating facilities. Indeed, the Federal Power Commission Northeast Regional Advisory Committee estimates that over 80 percent of the electric power needs of the region will be met by nuclear fuels by 1990.

Another area of interest in the inventory is the solid waste disposal system. Seventy-three percent of the 1,779,000 tons per year of solid waste generated is disposed of by burning, and 25 percent by sanitary landfill. Only 31 percent of the refuse is burned in incinerators and 12 percent in municipal

incinerators. Of the 1,291,000 tons per year disposed of by burning, 737,000 tons per year are burned on site or in open dumps (41 percent of the total) [Figure 24].

Pollutant emissions from the extensive burning of solid wastes, both on-site and in dumps, constitute a significant element of the total emissions picture in the study area.

AIR QUALITY ANALYSIS

This discussion of emissions does not provide information as to the people and property affected. While location and amount of emissions constitute an important element in air quality analysis, a regional boundary cannot be determined from emission data alone.

Ideally, effects on people and property could be studied by review of measured air quality data, gathered over sufficient time and at enough points to be reliable. The Merrimack Valley area is similar to most regions in not having developed air sampling networks sufficiently comprehensive to be used as the sole guide in assessing ambient air quality.

As an alternative, a meteorological diffusion model has been used to compute theoretical pollutant concentrations in the ambient air, using a combination of emissions data and meteorological factors. While there are inherent limitations in the model, it can be used as a guide in projecting theoretical air quality.

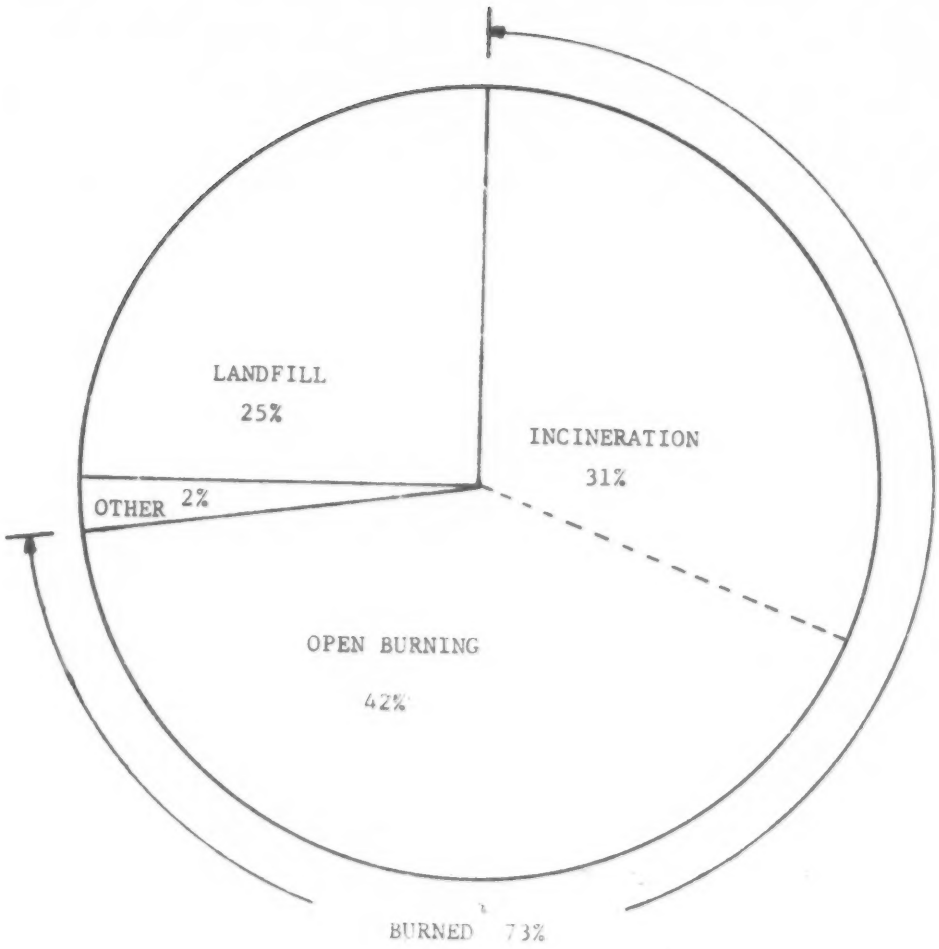

FIGURE 24 - Solid Waste Disposal Practices

Meteorology and Climatology

In order to understand the mechanism by which emissions are dispersed, a review of meteorological data is needed.

The study area is characterized by prevailing westerly winds; cool dry air from the northwest and warm, moist air from the southwest. The flow of air is generally offshore with occasional northeast storms off the Atlantic (Figure 25). In general, the weather is favorable toward transport and dispersion of airborne pollutants. Exceptions occur during periods of stagnant weather, usually associated with a slow-moving high pressure system characterized by light surface winds and temperature inversions which form an air "lid" over the area. The study region experienced about ten episodes of such stagnation which lasted four days or more over the past 25 years; i.e., about one every 2.5 years. The number of individual stagnant days averages about two per year (Table XV).

Table XV

Average Mixing Depths by Season and Time of Day (meters)

Season	Morning	Afternoon	Average
Winter	625	800	712
Summer	390	1,300	845
Annual (all four seasons)	529	1,050	789

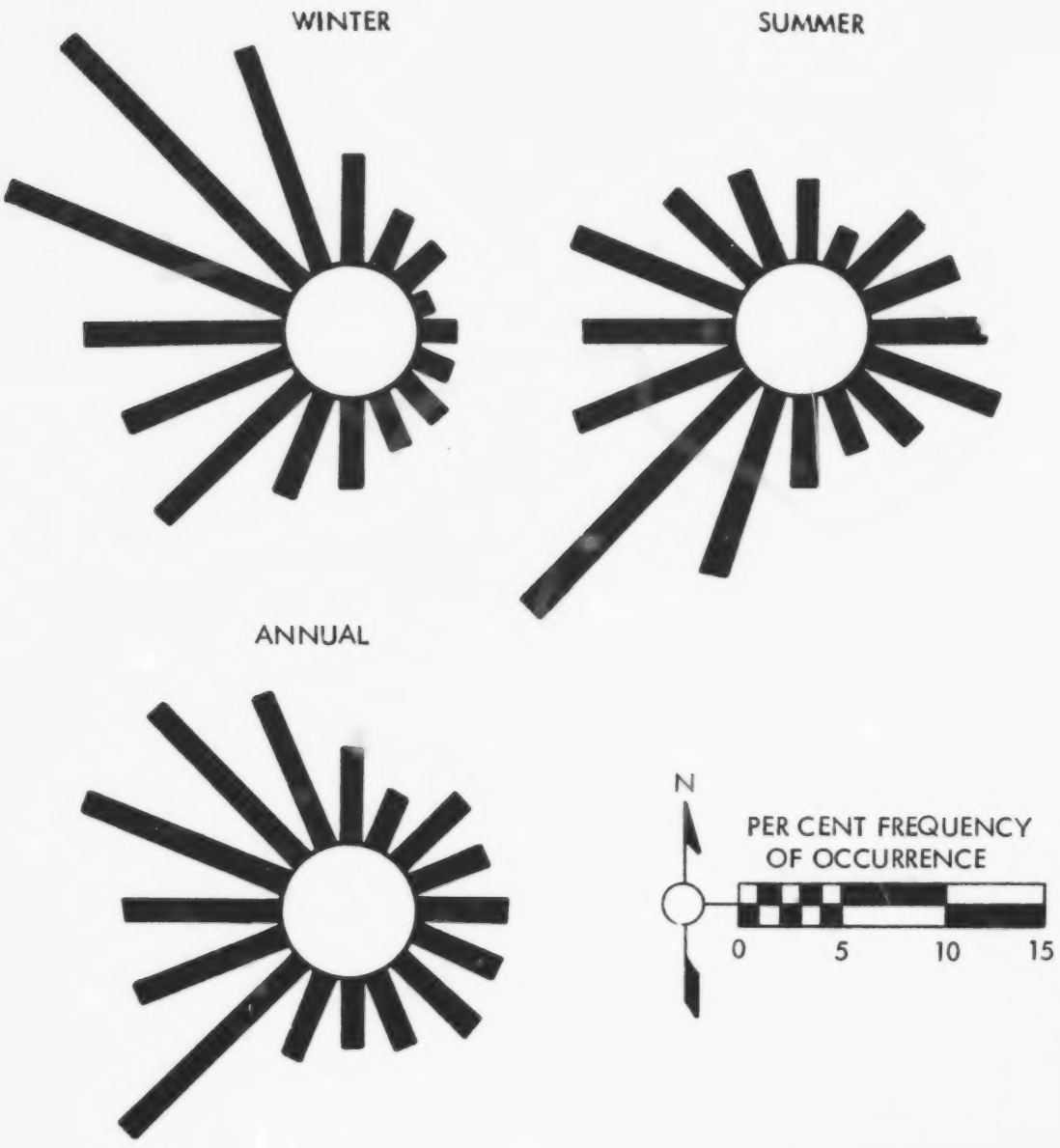

FIGURE 25 - Wind Direction Percent Frequency of Occurence for Various Averaging Times

Large scale storms are more frequent and intense in winter and spring, so that stagnant weather conditions are most likely to occur during cloudless Indian summer days.

Air Sampling Data

The concentration contours developed from the diffusion model are shown in Figures 26, 27, and 28, as annual average theoretical concentrations of sulfur oxides, particulates, and carbon monoxide. As might be expected, the concentrations bear a strong relationship to the extent of urbanization and the location of electric power generating stations. The concentrations show a moderate displacement easterly from the principal emission sources because of the prevailing westerly air currents. Winter and summer contours would not show marked differences from the annual averages except for higher winter concentrations as the result of increased fuel consumption.

Limited sampling data available in the area tend to show higher concentrations than the model developed. A 1963 sample in Lowell, for example, produced an annual arithmetic mean particulate concentration of 75 $\mu g/m^3$, and a similar sample in Lawrence in 1965 showed 74 $\mu g/m^3$. While the models may not demonstrate with precision the amount of concentration, they do have value in showing relative geographic concentrations.

FIGURE 26 - Theoretical Annual Average Concentrations of Sulfur Oxides (Values in Micrograms per Cubic Meter)

FIGURE 27 - Theoretical Annual Average Concentrations of Particulates (Values in Micrograms per Cubic Meter)

FIGURE 28 - Theoretical Annual Average Concentrations of Carbon Monoxide (Values in Micrograms per Cubic Meter)

PROPOSED AIR QUALITY CONTROL REGION

Subject to the scheduled Consultation, it seems appropriate to consider an air quality control region in the Merrimack Valley-Southern New Hampshire area consisting of the following townships located in the Counties of Essex and Middlesex in Massachusetts, and in the Counties of Belknap, Grafton, Hillsborough, Merrimack, Rockingham, and Strafford in New Hampshire (area included shown in Figure 29):

In Massachusetts

Essex County	Middlesex County
Andover	Ayer
Amesbury	Billerica
Boxford	Carlisle
Georgetown	Chelmsford
Groveland	Dracut
Haverhill	Dunstable
Lawrence	Groton
Merrimac	Littleton
Methuen	Lowell
Newbury	Pepperell
Newburyport	Tewksbury
North Andover	Tyngsborough
Rowley	Westford
Salisbury	
West Newbury	

In New Hampshire

Belknap County	Grafton County
Tilton	Alexandria
	Bridgewater
	Bristol
	Hebron

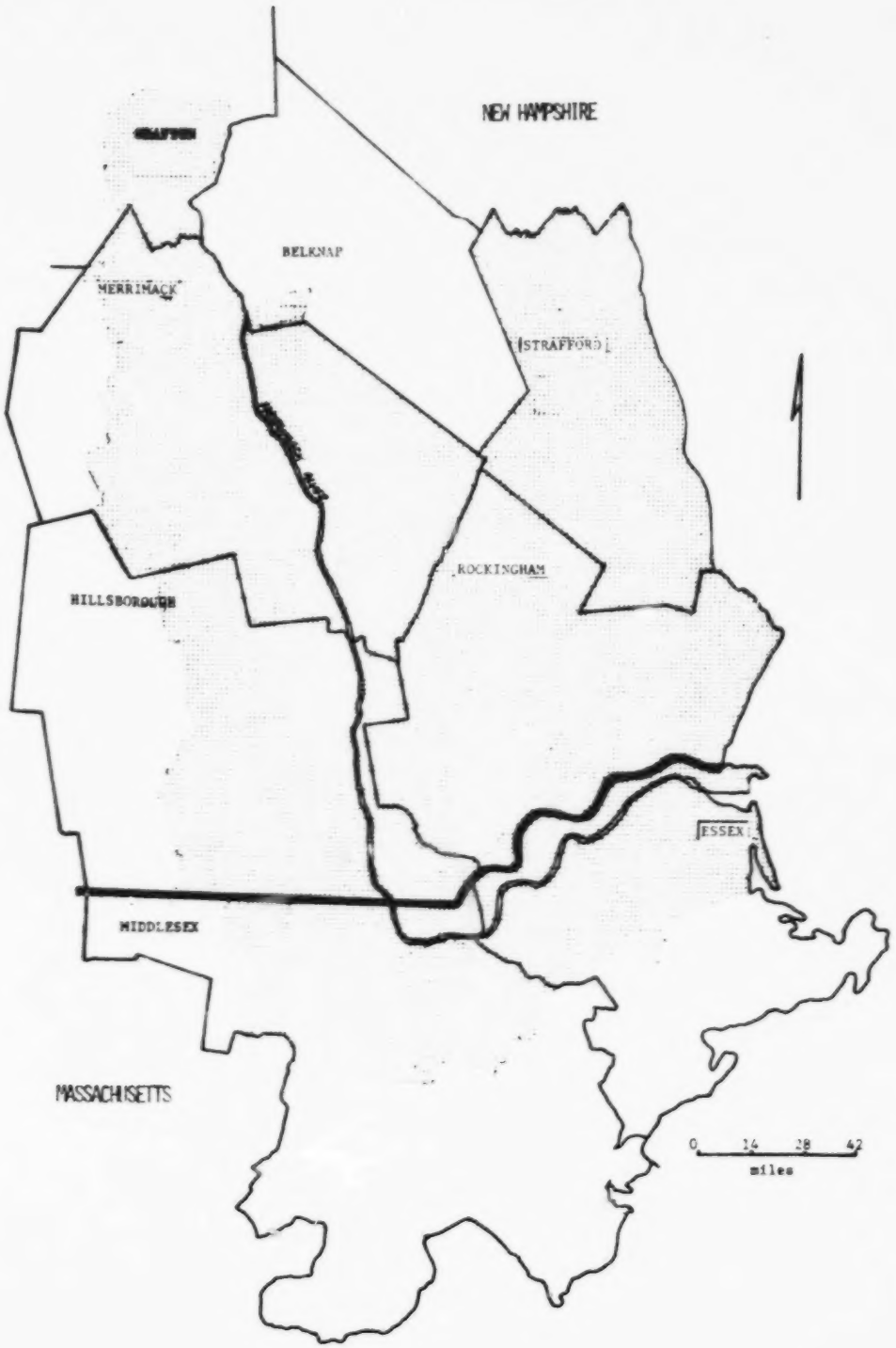

FIGURE 29 - Proposed Air Quality Control Region

In New Hampshire (continued)

Hillsborough County

Amherst
Bedford
Brookline
Goffstown
Hollis
Hudson
Litchfield
Lyndeboro
Manchester
Mason
Merrimack
Milford
Mont Vernon
Nashua
New Boston
Pelham
Weare
Wilton

Merrimack County

Allenstown
Andover
Boscawen
Bow
Canterbury
Chichester
Concord
Danbury
Dunbarton
Epsom
Franklin
Henniker
Hill
Hooksett
Hopkinton
Loudon
Northfield
Pembroke
Pittsfield
Salisbury
Warner
Webster

Rockingham County

Atkinson
Auburn
Brentwood
Candia
Chester
Danville
Deerfield
Derry
East Kingston
Epping
Exeter
Fremont
Greenland
Hampstead
Hampton
Hampton Falls
Kensington
Kingston
Londonderry
Newcastle
Newfields
Newington
Newmarket
Newton
North Hampton
[illegible]hwood
Nottingham
Plaistow
Portsmouth
Raymond
Rye
Salem
Sandown
Seabrook
South Hampton
Stratham
Windham

In New Hampshire (continued)

Strafford County

Barrington	Milton
Dover	New Durham
Durham	Rochester
Farmington	Rollinsford
Lee	Somersworth
Madbury	Strafford
Middleton	

Discussion

An air quality control region should meet three basic criteria:

1. It should encompass most pollution sources as well as most people and property affected by the sources.
2. It should include those areas where industrial and residential growth may create significant future problems.
3. It should be consistent with unified and cooperative administration of the region's air resources.

The proposed Region for the Merrimack Valley-Southern New Hampshire area would satisfy the broad requirements of these criteria.

The discussions in preceding sections of technical, urban, and governmental factors relevant to a determination of the Region's boundaries lead to the following conclusions:

1. Most of the pollution sources in the Merrimack Valley-Southern New Hampshire area are located within the proposed Region.

Sulfur oxides pollution sources are concentrated in Merrimack and Rockingham Counties, New Hampshire, where electric power plants

are located, and in the Massachusetts portion of the proposed Region, where there is a dense concentration of industrial and institutional users of residual fuel oil. Particulates emissions, largely from solid waste disposal practices and fuel combustion by stationary sources, are highest in volume in the Massachusetts portion of the proposed Region and in Merrimack and Hillsborough Counties, New Hampshire. Carbon monoxide emissions, arising mainly from the operation of motor vehicles, are highest in the Massachusetts portion of the proposed Region and in Hillsborough and Rockingham Counties, New Hampshire. No major sources of pollution presently exist in the western portions of Merrimack and Hillsborough Counties outside of the proposed Region.

Most of the people and property affected by the dispersion of pollutants are located within the boundaries of the proposed Region, with major concentrations of population and industry in bands along the Merrimack Valley, on the Atlantic Coast, and on the New Hampshire side of the Piscataqua River. The western portions of Merrimack and Hillsborough Counties are not heavily populated or industrialized, although a few medium to large plants have been established. These areas are not generally affected by pollution sources in the Merrimack Valley because of prevailing westerly winds.

2. The Region as proposed would take account of the most probable future directions of residential and industrial growth.

The present expectation is that growth will largely fill out and intensify the present "U"-shaped physical pattern of urban development in the Region. The cities and towns within the Region which have long been linked by geography, a common pattern of manufacturing activity, and an integrating transportation system, are likely to increase their economic interdependence. As the Massachusetts portion of the Region grows, Southeastern New Hampshire anticipates "spillover" additions to its residential population and industry, and there may be increased crossflows of commuters between contiguous areas in the two States. The present major highway system both serves the existing pattern of urbanization and reinforces the likelihood of its continuation in the future. The western portions of Hillsborough and Merrimack Counties are not expected to grow at the rates projected for the remainder of Southeastern New Hampshire.

3. The proposed Region would permit a unified and cooperative administration of its air resources.

The Massachusetts portion of the proposed Region is identical in composition with the State's proposed Merrimack Valley Air Pollution Control District. The district is one of six areas into which the State has been divided for the development of local air pollution control programs under the administration of the Massachusetts State Bureau of Air Management.

The New Hampshire portion of the proposed Region consists of the New Hampshire State planning districts 7, 12, 13, 14, 15, 16, and 17. These are among 17 districts into which the State has been divided for planning purposes to overcome problems previously presented to municipalities by a multiplicity of overlapping or conflicting regional groupings. In determining the planning district boundaries, the State took account of existing intergovernmental groupings and made judgments on linked urban growth.

By including the above New Hampshire planning districts in the proposed Region, Strafford and Rockingham Counties are included in their entirety. Strafford County municipalities are all within district 17. Rockingham County municipalities are all accounted for in districts 12, 13, 15, 16, and 17. The portions of Hillsborough County included in the proposed Region are parts of districts 13 and 14, while those included in Merrimack County are parts of districts 7, 12, and 13.

In order to include the whole of district 7, the municipalities of Alexandria, Bridgewater, Bristol, and Hebron in Grafton County, and Tilton in Belknap County, have been added to the proposed Region even though they were not within the study area. The alternative of excluding district 7 altogether did not appear justified in view of the contiguity of relatively dense residential settlement north of Concord in Boscawen and Franklin.

On the other hand, municipalities in the western portion of Merrimack and Hillsborough Counties are not included in the proposed Region because they are parts of State districts 9 and 11, whose urban centers are not in the Merrimack Valley area. District 9, with its urban center in Claremont at the western edge of the State, would appear to be more logically a part of the Connecticut River urban area.

4. While district 11, the Peterborough area discussed in this study, has not been included in the Proposed Region, consideration might be given for its inclusion in view of the beginning of large-scale manufacturing in Peterborough and Hillsborough.